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## International Input-Output Association

TENTH INTERNATIONAL CONFERENCE ON INPUT-OUTPUT TECHNIQUES DECIMA CONFERENCIA INTERNACIONAL DE TECNICAS INPUT-OUTPUT

SEVILLE/SPAIN, MARCH 29- APRIL 2, 1993

## PĄPERS FOR THE PLENARY SESSIONS

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Jan Oostrehaven:

## PLENARY SESSION PIV: METHODOLOGICAL, MATHEMATICAL AND COMPUTATIONAL ASPECTS OF MULTISECTORAL MODELS

## CHAIR: Thijs ten Raa

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\begin{array}{ll}
\text { Donald Gilchrist / An Equilibrium Analysis of Regional Industrial } \\
\text { Larry St. Louis: } & \text { Classification }
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$$

E. Dietzenbacher: On the Basis of Multiplier Estimates

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Graham Pyatt Modelling Commodity Balances

PLENARY SESSION PV：INPUT－OUTPUT ANALYSIS Aレニ •・ー・・ー ACCOUNTING

CHAIR：Graham Pyatt
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Michel Séruzier：IO Table as a Central Element in National Accounts

Kenneth Reinert／Social Accounts and the Structure of the ：：－
D．Roland－Holst／American Economy
Clinton Shiels：

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H．Ota：The 1985 Japan－US－EC IO Table
Steven Keuning：National Accounts，SAMs and SESAME：A System of Economic and Social Accounting Matrices and Extensions

Carsten Stahmer：Internacional Trade and Environmental Cost－Accounting

# Input-Output Structure of Scientific Knowledge 

## Wassily Leontier Assisted by Karin Nauphal

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1．There exists more than a superficial similarity between the interdependence of different industries within the framework of a national，or even the entire international economy，and the relationships between different disciplines within the broad highly diversified area of scientific knowledge．Both the economic growth and the advancement of scientific knowledge are characterized by structural change which involve，in the long run，disappearance of old and introduction of entirely new products and ideas．

Measuring and counting plays such an important role in economic transactions that the use of quantitative approach in the description of the interdependence between the different sectors of a complex national economy began more than tio hundred years ago． Although philosophical discourse about the relationship between different fields of scientific inquiries has ieer conducted from times immortal，plausible generally acceptaije＝eこうȯs of measuring the production，circulation，and utilizaこ：气．$\quad$ se scientific knowledge became available only thirty years asこ．Fi．e invention by
 of their practical use as a numerica』 ニモミミニニミ ニミ research
 analysis of scientific knowledge．


 time of publication of the citing and the こここシ
of the steadily growing demand systematic compilation of citation indices become a profitable business. The first and best known enterprise engaged in it is the Institute for Scientific Information located in Philadelphia U.S.A. Several hundreds of its employees are now processing current issue of some 2600 leading scientific journals and thus maintain a data base that goes back to the year 1981. Several other Organizations are engaged in similar activities.
2. It has become a common practice in academic circles and in scientific administration to consider in assessing the importance of a scientific paper the number of references made to it in otheis scientific papers. A paper that has been often quoted is with good reason being considered to be more important, i.e., to have made a greater contribution to knowledge than a paper that has been seldom quoted or even not at all.

The total number of citation referring to articles published -
over a year, or a period of several years -- in a particular field can be used as a measure of the total output of researcher or research organizations working in the field. The total number of citation made in these articles to other scientific articles published in the same or any other field can be used as a measure of the total input of new knowledge used in that field in the process of generating its own output.

In particular, the number of citations made in articles published in field $A$ to articles published in field $B$, can be interpreted as measuring the amount of new knowledge delivered from
field B to field A. The broader is the definition of a particular field the more often will articles published in it contain references to articles classified as belonging to the same field. Generation of one particular kind of knowledge as a rule involves systematic use of other kinds of knowledge. This accounts for the existence not only of direct but also indirect interdependence between different sciences. A systematic record of citation flows between different kinds of scientific journals can thus be interpreted as reflecting the flow of the knowledge between different entities engaged in its production.

The total amount of scientific labor required to produce one unit of output (one citation) in a particular field consists not only of a direct contributions by researchers working in that particular field but also indirect contributions by those working in fields producing other kind of new knowledge that constitutes the intellectual input in that field.

The Input-Output methodology first introduced fifty years ago and widely used in description and analysis of economic systems can now be adopted and effectively employed in quantitative description and theoretical modelling of relationships between different fields of scientific knowledge.

Information on the number of scientists employed, and of the research expenditures incurred in each field of scientific research, incorporated in an Input-output model of interdisciplinary relationships can provide a link with the analysis of the economic aspects of production of scientific knowledge and thus pave the way to inclusion of a knowledge sector in analysis of the input structure of particular regional,
national, and even of the entire international economy. Export and import of citation could then be described and, to some extent, explained alongside with exports and imports of ordinary goods and services.
3. The representational interdisciplinary flows of knowledge by an Input-Output table is illustrated by the simple numerical example in Table 1.1; there are four scientific fields, mathematics, physics, chemistry and biology, listed on top of the first four columns and at the left of each row. The fields of knowledge are assigned a sector number appearing below the field name in the columns and to the right of it in the rows; mathematics for example has been assigned sector number 1.

The numbers in each cell of the table represent the number of citations that articles belonging to the column-field make to articles written in each of the 'row-field' thus the entries in each row reflect the flows of knowledge from the row-field to the fields listed on top of each column, they represent the 'output distribution' of the row-field; for example the first row in Table 1.1 reveals that articles in mathematics (math), have been cited 21 times by articles in the same field, 13 times by articles in physics (phys), 8 times by articles in chemistry (chem) and 3 times by articles in biology (biol). Read column-wise, the entries indicate the 'input distribution' of a field, the citations that a column-field absorbs from each of the row-fields; for example, the first column, shows that mathematics cited 21 times articles from the same field, one article from physics, and 0 articles from
chemistry or biology.
Scientific knowledge is also delivered to 'final users' that do not belong to the scientific disciplines; the uses of knowledge that are not recorded in the interfield part of the citation table are entered in the column of "final demand"; these entries include, for instance, citations made to the scientific literature by popular scientific magazines, textbooks, encyclopedias and also references to the scientific literature contained in patents. In Table 1.1, the final demand sector has cited mathematics twice, physics 12 times, chemistry 11 times and biology 5 times. The last column of the table shows Total outputs i.e., the sums of the entries in each row; it represents the total number of citations that a row-field has received from all scientific disciplines in addition to the final demand sector; for example, mathematics has a total output of 47 citations of which 45 are from the scientific disciplines and 2 from the final sector.

The two bottom rows of Table 1, shows the number of scientific personnel employed in each of the fields (named at the top of the corresponding column), and the financial expenditures incurred in research in the respective fields; again looking at the mathematics column we see that 44 scientists were employed and $\$ 450$ were incurred in research related expenditures. Overall, 120 scientists were employed in all four disciplines, with a total research cost of $\$ 1650$. With that set of information added to the citation data, the entire input structure of each column-field is described, both in terms of knowledge flows and in terms of its' primary inputs.

A general mathematical representation of the numerical table is given in table 1.2. The interdisciplinary flows of knowledge are described by the variables $x_{4,}$ for $i, j=1,2,3,4, j$ that represent the number of citations to articles written in field $i$, by articles written in field $f$; for example, $X_{1,3}$ represent the number of citations made to field 1 (mathamatics), by articles in field 3, (chemistry) which is equal to 8 citations, in Table 1.1. The final demand variables are denoted by $Y_{i} 1=1,2,3,4 ;$ which represent the number of citations that each field i receives from the final demand sector. The total output of a field $i x_{1}$ is equal to the sum of the interdisciplinary and final demand citations made to it; similarly, $I_{4}$ and $c_{1}, i=1,2,3,4$, represents the number of employed scientists and the dollar research expenditures, in field i, respectively.

The entire system can be descriked by the following set of equations:

$$
\begin{align*}
\text { sectoral output: } & X_{i}=\sum_{j=1}^{4} X_{i, j}+Y_{i} \\
\text { employment: } & L=\sum_{j=1}^{4} L_{i}  \tag{1}\\
\text { expenditures: } & C=\sum_{j=1}^{4} C_{i}
\end{align*}
$$

4. From the preceding Input-Output table we can derive tables or matrices of 'input coefficients' which give the average input requirement per unit of the output of each field; these are obtained by dividing each element of a column-field (the inputs to that sector) by the total of its corresponding row field (the total
output of that field); square interdisciplinary matrix shown on Table 1.3, contains these 'structural' coefficients, derived from Table 1.1: they describe the amounts of inputs received by each particular scientific field from itself and from each of the other fields - per unit of its total output; these inputs coefficients are of the form $a_{i j}=X_{h j} / X_{j}$, for $i, j=1,2,3,4$. In Table 1.3 for example, the first element in column 2 (phys), $\mathbf{a}_{1,2}$ is equal to 0.25 , which is obtained by dividing $X_{1,2}=13$ by $X_{2}=51$ from Table 1.1; In that case, for every unit of citation that physics obtain from any field, it makes, on average, 0.25 citation to mathematics. Similarly, the two vectors in the bottom of Table 1.3, contain the employment and cost coefficients per unit output; for example, mathematics requires 0.9 scientist and 9.6 dollars for every citation produced. Table 1.4 describes the corresponding mathematical notation used for the definition of the structural tables; the $A$ matrix corresponds to the interdisciplinary matrix of average input requirements per unit of output; vectors 1 , and $c$ contain the average labor and cost input coefficient (per unit of total output).

The corresponding system of equation can be written as:
sectoral output: $X_{i}=\sum_{j=1}^{4} a_{i, j} \cdot X_{j}+Y_{i}$
employment: $L=\sum_{j=1}^{4} l_{i} \cdot X_{j}$
expenditures: $C=\sum_{j=1}^{4} c_{i} \cdot X_{j}$

In matrix notation (2) can be expressed as:
sectoral output: $X=A \cdot X+Y \quad$ or $\quad Y=(I-A) \cdot X$
employment: $L^{\prime}=\hat{l} \cdot X$
expenditures: $C^{\prime}=\hat{c} \cdot X$

Where $Y$ is the vector of final demand, $X$ is the vector of total output, $I$ is an identity matrix 1 and $c$ are the diagonal matrices of the employment and cost coefficients 1 and $c, a n d L^{\prime} c^{\prime}$ are the transpose of the vectors $L$ and $\dot{C}$ respectively.
5. The solution of the system of equation (3) is,
sectoral output: $X=(I-A)^{-1} \cdot Y$

$$
\begin{equation*}
\text { employment: } \quad L^{\prime}=\hat{l} \cdot\left[(I-A)^{-1} \cdot Y\right] \tag{4}
\end{equation*}
$$

expenditures: $\quad C^{\prime}=\hat{c} \cdot\left[(I-A)^{-1} \cdot Y\right]$

The central elements in this computation is the square inverse matrix $(I-A)^{-1}$, given in numerical form in Table 1.5 (derived from Table 1.3), and presented in general mathematical notation in Table 1.6. This matrix is similar in form to the matrix $A$, with each row and column is labelled by the corresponding field of knowledge. Each element of this inverse, denoted by $s_{i j}$, represents the total - direct and indirect - contribution by field i to the production of every unit of citation delivered by field $j$ to final users; for example, $8_{1,2}=1.08$ shows that for every citation 'delivered' by physics to final users, mathematics contributes directly and indirectly, 1.08 citation to it; a column of this matrix therefore, specifies the total inputs requirement of the corresponding field, from each field of knowledge, for its delivery
of a unit of output to final users; for example, column 3 in Table 1.5 specifies the total requirement to the delivery of one citation from chemistry to the final users; it requires $\mathbf{8}_{13}=1.25$ units of citation from mathematics, $\mathbf{8}_{21}=1.09$ unit of citation from physics, $\mathbf{s}_{3,3}=2$ unit of citation from chemistry and $\mathbf{s}_{4,3}=0.07$ unit of citation from biology.

The employment and expenditures requirements for the delivery of one unit of citation to the final sector can be calculated by multiplying the scientists and cost input coefficients in Table 1.3 by the corresponding sectoral total input requirement obtained above. For example, to deliver one unit of citation from chemistry to the final sector, 3.7 scientists need to be employed (scientists coefficient row vector times chemistry column in the inverse) and 47 dollars of expenditures incurred (cost coefficient row vector times chemistry columns in the inverse). Similar computations can be carried out to determine the levels of output, employment and the total costs required directly and indirectly to deliver to final users one unit of citation of each field; the requirement to any bill of final demand can be calculated similarly based on this matrix; Table 1.7, reports the result of computations for the total requirements to satisfy the original final demand vector; the computed requirements for output, employment and costs, obviously replicate the original data.
6. Since the diffusion of knowledge between the different fields is a dynamic process, the explicit representation of time sequences
in the modeling of interdisciplinary relationships is very important for revealing the structure of the time lags in the transfer of knowledge among its various branches, and capturing the process of 'structural changes' i.e., changes in the composition of inputs of each field, that in the long run leads to the gradual disappearance of old and the introduction of entirely new fields of knowledge.

This section describes a three period version of the Interdisciplinary Input-output model of the previous section using the framework of the multiperiod Input-Output model developed in Leontief (1989) that is particularly suited to the description of interdisciplinary relationships under conditions of structural change. The flow of knowledge between the scientific disciplines is measured by the number of citations each field makes to the other fields and to itself within a time period during which it is generated and across several future time periods. In this example there are three periods, 1, 2 and 3, and there are three fields of knowledge mathematics, physics and chemistry in the first two periods, and fourth one biology is introduced in the third period, in order to illustrate the way the model takes into account structural change in the scientific disciplines.

A numerical example of the flows of citations between the different fields and time periods are given in Table 2.1, by the matrices $X_{1,1}, X_{1,2}, X_{1,3}, x_{2,2,} X_{2,3}$ and $\mathbf{x}_{3,3}$. Each of these matrices $\mathbf{x}_{1, j}$, is similar to the flow table in the previous section; the first subscript refers to the period in which the cited articles were
written and, the second subscript refers to the period the citing articles were written. Articles written in period 1 can be cited in periods 1,2 , and $3\left(x_{1,1}, \mathbf{x}_{1,2}, \mathbf{x}_{1,3}\right)$; articles written in period- 2 can be cited in periods 2 , and $3\left(x_{2,2}, x_{2,3}\right)$; articles written in period 3 can only be cited in periods $3\left(x_{3,3}\right)$. $x_{1,1}, x_{1,2}, x_{2,2}$ are (3 x 3 ) matrices ( 3 fields cited and 3 fields citing); $X_{1,3}, X_{2,3}$ are ( $3 \times 4$ ) matrices ( 3 fields cited and 4 fields citing) ; and $X_{3,3}$ is a (4×4) matrix (4 fields cited and 4 fields citing). Each of these matrices $X_{i, j}$ is similar to the flow table in the previous section; the elements have the same interpretation. In $x_{1,2}$ for example, the first column refers to the citations that articles written in mathematics in period two have made to articles written in period 1. They cite 4 articles in mathematics, one article in physics, and none in chemistry.

The final demand vectors $Y_{1}, Y_{2}$ and $Y_{3}$ in Table 2.1 , record the citations that final users make to the different fields in different periods of time; the subscript refers to the period the cited articles have been written.

As in the 'static' Input-output model of the previous section data on scientists' employment and research expenditures in each field, in each period are also shown in Table 2.1.
7. The matrices in Table 1 and Table 2 can be combined to form the following three period time-phased interdisciplinary inputoutput model:

| time | $\overbrace{\text { period1 }}$ | $\overbrace{\text { period } 2}$ | $\overbrace{\text { period } 3}$ |  | $\overbrace{}^{\text {Demand }}$ | $\overbrace{}^{\text {Total }}$ |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| period 1 \{ period 2 period 9 | $\left[\begin{array}{c}X_{1,1} \\ \cdots \\ 0 \\ \cdots \\ 0\end{array}\right.$ | $\begin{array}{cc}\vdots & X_{1,2} \\ \vdots & \cdots \\ \vdots & X_{2,2} \\ . & \cdots \\ \vdots & 0\end{array}$ | $\left.\begin{array}{c}X_{1,3} \\ \cdots \\ X_{2,3} \\ \cdots \\ X_{3,3}\end{array}\right]$ |  | $\left[\begin{array}{c} \\ Y_{1} \\ \cdots \\ Y_{2} \\ \cdots \\ Y_{3}\end{array}\right]$ | $=\left[\begin{array}{c} \\ X_{1} \\ \cdots \\ X_{2} \\ \cdots \\ X_{3}\end{array}\right]$ |
| Scientists Costs | $\left[\begin{array}{c}L_{1,2} \\ \cdots \\ C_{1,1}\end{array}\right.$ | $\begin{array}{ll}\vdots & L_{2,2} \\ \vdots & \cdots \\ \vdots & C_{2,2}\end{array}$ | $\left.\begin{array}{c}L_{3,3} \\ \cdots \\ C_{3,3}\end{array}\right]$ |  |  | $=\left[\begin{array}{c}L \\ \cdots \\ C\end{array}\right]$ |

where $x_{1}, x_{2}$ and $x_{3}$ are the vectors of total outputs of the fields in each period; this system corresponds to the system of equations (1). Table 2.2, and Table 2.3 are constructed in the way described above; the sum of citations a row "delivers" to interfield transactions, through all periods, and to final users constitutes the total output of the field. Table 2.2 contains the mathematical notation of the variable in each cell and, table 2.3 the corresponding numerical example.

This intertemporal model contains a larger interdisciplinary flow matrix, but the interpretation of it's rows and columns is basically the same as in the discussion of the 'static' flow table
of the previous section. In order to see the fundamental similarity, following Leontief (1989), we can interpret the time period as another qualitative characteristic of the variables, so that articles written in a specific field in two different periods of time are considered as belonging actually to two different fields; i.e., citations produced in the same field in two different periods are considered as being generated in two different sectors.

In Tables 2.2, and 2.3 the fields have been assigned a sector number $1,2, \ldots .10$, so that mathematics in period 1 is assigned sector number 1 , in period 2 sector number 4, and in period 3 sector number 7, and similarly for the other fields; we end up with a $10 \times 10$ interdisciplinary citation flow matrix. In Table 2.3, reading column-wise sector 9 (which refers to articles in chemistry written in period 3), for example, the entries indicate the number of articles that this sector is citing from each row-sector (i.e., from the fields in the different periods of time); it makes one citation to sector 1 (articles in mathematics, written in period 1), two citation to each of sectors 2 and 3 (articles in physics and chemistry respectively, written in period 1), two citation to each sectors 4 and 5 (articles in mathematics and physics respectively written in period 2), four citation to sector 6 (articles in chemistry, written in period 2), and one citation to sector $7,8,9$, and 10 (articles in mathematics, physics, chemistry and biology respectively, written in period 3).

Reading sector 9, row-wise now, we see that it "delivers" no citation to the first 6 column sectors, obviously, since the latter refers to articles written in the two previous period, it also "delivers", nothing to sector 7 , and 8 , one citation to sector 9 , and three citations to sector 10 ; moreover sector 9 delivers 4 citations to the final demand vector; the total output of sector 9 which is recorded at the end of the row is equal to the sum of all of those citations which amounts to eight in the present case,

The employment and expenditures in each field are given at the bottom of the corresponding column.
8. Since the intertemporal model is structurally equivalent to a static model, the same procedures applies; from the flow tables we compute the structural matrices who's elements are the average input requirement per unit of output; the basic difference lies in the fact that the intertemporal flow matrix is block triangular "reflecting the fundamental ordering function of time (Leontief,(1989))".

The corresponding input coefficients, matrix A is given in Table 2.4; its elements are obtained by dividing each element of a column sector (the inputs to that sector), by the total of it's corresponding row sector (the total output of that sector).

For our numerical example the magnitude of these direct input coefficients are presented in Table 2.5.

From this time phased matrix of input coefficients we can obtain the time-phased inverse (I - A) showing the total i.e., direct plus indirect input requirements for delivery to final
demand of one citation produced by each sector in each period of time. This matrix is given in Table 2.6 for the numerical example. The interpretation of this intertemporal inverse is similar to that of a static inverse, in the sense that although the inputs required from previous time period are explicitly represented, the present formulation allows them to be treated as just originating from other sectors; therefore the basic structure and hence the interpretation remains, unchanged.

Looking at rable 2.6, we see that to deliver in period 2 one citation to its final users, sector 6 (articles written in chemistry in period 2) absorbs directly and indirectly 0.25 citation from sector 1, 0.31 citation from 2, 0.38 citation from sector 3, 0.21 citation from 4, 0.28 citation from sector 5, 1.23 citation from itself, and none from the other sectors.
9. The solution of the intertemporal model is equivalent to the solution to the "static" model given by the system of equations (4); the "static" Input-Output equation still hold in this "quasidynamic" model; The output solution is given by the standard equation $X=(1-A)^{-1} Y$ which can be represented in the present case by:


The result of this computation using the data of the numerical example is reported in Table 2.7. The total output required to deliver the final demand vector is given for each sector, along with the sectoral requirements in terms of the number of scientists employed and the research costs incurred that were calculated according to the system of equations (4). In that particular case, because the vector of final demand used here is the one provided originally in the example, the requirements of output, scientists and research costs match exactly the original data.
10. The possibility of obtaining very detailed classification of the scientific activities, with the corresponding data on their citation flow, ordered and analyzed through an Input-output framework could allow for a systematic investigaion of the relationships between different fields of science and the nature of the interdependencies and of the feedback effects at work and their implications for employment and research expenditures; standard computational techniques can be used to locate important clusters of closely interrelated disciplines so as to approximate a "pecking order" between the different fields. Moreover, the possible identification of the national origin of the scientific ideas could allow a study of the international flows of knowledge and the interdependencies and international linkages as is commonly done in economic input-output analysis.

## References

Leontief, W. (1986). Input Output Economics, 2nd ed. (New York, Oxford University Press), Ch. 2.

Leontief, W. (1989). "Input-Output Data Base for Analysis of Technological Change," Economic Systems Research, Vol.1, No. 3, 287295.

The Citation Flow Tables
Table 1.1

| fields |  | math | phys | chem | biol Final | Total |  |
| :--- | ---: | ---: | ---: | ---: | ---: | ---: | ---: |
|  | $\#$ | 1 | 2 | 3 | 4 | Demand | output |
| math | 1 | 21 | 13 | 8 | 3 | 2 | 47 |
| phys | 2 | 1 | 23 | 11 | 4 | 12 | 51 |
| chem | 3 | 0 | 5 | 17 | 8 | 11 | 41 |
| biol | 4 | 0 | 0 | 1 | 2 | 5 | 8 |


| scientists |  | 44 | 32 | 36 | 8 |
| :--- | :--- | ---: | ---: | ---: | ---: |
| $S$ cost |  | 450 | 700 | 380 | 120 |

Table 1.2

| fields | math |  |  | c | chem |  | Final | Total |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | \# | 1 | 2 |  | 3 | 4 | Deman | output |
| math | 1 | $\mathrm{X}_{1.1}$ | $\chi_{1.2}$ | $\chi_{1}$ | 3 | $x_{1.4}$ | $Y_{1}$ | $\mathrm{X}_{1}$ |
| phys | 2 | $x_{21}$ | ${ }^{1.2}$ | $x_{2}$ | 3 | $x_{24}$ | $Y_{2}$ | $x_{2}$ |
| chem | 3 | $\mathrm{x}_{3.1}$ | ${ }^{2}$ | $x_{3}$ | 3 | $\mathrm{X}_{3.4}$ | $Y_{3}$ | $x^{2}$ |
| biol | 4 | $\mathrm{X}_{4}$ | $\mathrm{X}_{1}$ | $\mathrm{X}^{+}$ |  | $\mathrm{X}_{4,4}$ | $Y_{1}$ | ${ }^{1}$ |


| scientists | $L_{1}$ | $L_{1}$ | $L_{3}$ | $L_{4}$ |
| :--- | :--- | :--- | :--- | :--- |
| $S$ cost | $C_{1}$ | $C_{2}$ | $C_{3}$ | $C_{4}$ |

## Direct requirement matrix

Table 1.3

| fields | math |  |  |  |  |
| :--- | ---: | ---: | ---: | ---: | ---: |
|  | phys | chem | biol |  |  |
| math | 1 | 1 | 2 | 3 | 4 |
|  | 0.45 | 0.25 | 0.20 | 0.38 |  |
| phys | 2 | 0.02 | 0.45 | 0.27 | 0.5 |
| chem | 3 | 0 | 0.1 | 0.41 | 1 |
| biol | 4 | 0 | 0 | 0.02 | 0.25 |


| scientists |  | 0.94 | 0.63 | 0.88 | 1 |
| :--- | :--- | :--- | :--- | :--- | ---: |
| $S$ cost |  | 9.57 | 13.7 | 9.27 | 15 |

Table 1.4

| fields | math |  |  | ch | hem |  | bio |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | \# | 1 | 2 |  | 3 |  | 4 |
| math | 1 | $\mathrm{a}_{1.1}$ | $a_{1.2}$ | $\mathrm{a}_{1.3}$ |  | 1. |  |
| phys | 2 | $a_{21}$ | $a_{22}$ | $a_{22}$ |  | $a_{2}$ |  |
| chem | 3 | $a_{3.1}$ | $\mathrm{a}_{3.2}$ | $\mathrm{a}_{3.3}$ |  | $\mathrm{a}_{3}$ |  |
| biol | 4 | $a_{4}$ | $a_{4}$ | $\mathrm{a}_{13}$ |  | $a_{1}$ |  |


| scientists | $l_{1}$ | $l_{2}$ | $l_{3}$ | $l_{1}$ |  |
| :--- | :--- | :--- | :--- | :--- | :--- |
| $S$ cost |  | $C_{1}$ | $C_{2}$ | $C_{3}$ | $C_{1}$ |

Total (Direct and Indirect) Requirements per Citation
Table 1.5

| fields |  | math | phys | chem | biol |
| :--- | :---: | :---: | :---: | :---: | :---: |
|  | $\#$ | 1 | 2 | 3 | 4 |
|  | 1 | 1.85 | 1.08 | 1.25 | 3.31 |
| math | 2 | 0.08 | 2.05 | 1.09 | 2.86 |
| phys | 2 | 0.01 | 0.36 | 2.00 | 2.92 |
| chem | 3 | 0.00 |  |  |  |
| biol | 4 | 0.00 | 0.01 | 0.07 | 1.43 |

Table 1.6

| fields | math |  |  |  | phys |
| :--- | :---: | :---: | :---: | :---: | :---: |
|  | $\#$ | 1 | 2 | chem | biol |
|  | 1 | $\mathrm{~s}_{1.1}$ | $\mathrm{~s}_{1.2}$ | $\mathrm{~s}_{1.3}$ | $\mathrm{~s}_{1.4}$ |
| math | 1 | $\mathrm{~s}_{1.4}$ |  |  |  |
| phys | 2 | $\mathrm{~s}_{2.1}$ | $\mathrm{~s}_{2.2}$ | $\mathrm{~s}_{2.3}$ | $\mathrm{~s}_{2.4}$ |
| chem | 3 | $\mathrm{~s}_{3.1}$ | $\mathrm{~s}_{3.2}$ | $\mathrm{~s}_{3.3}$ | $\mathrm{~s}_{3.4}$ |
| biol | 4 | $\mathrm{~s}_{4 .}$ | $\mathrm{s}_{4.2}$ | $\mathrm{~s}_{4.3}$ | $\mathrm{~s}_{4.4}$ |

output, employment and cost requirement
Table 1.7

| fields |  | Final <br> Demand | Requirements |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: |
|  | S |  | Outpu: | Scientiss | Expenditures |
| math | 1 | 2 | 3 | 44 | 450 |
| phys | 2 | 12 | 14 | 32 | 700 |
| chem | 3 | 11 | 14 | 36 | 380 |
| biol | 4 | 5 | 9 | 8 | 120 |

Table 2.1.

Interdisciplinary flow tables
$X_{1,1}$
(periods 1-1)

| Field | math | phys | chem |
| :--- | :---: | :---: | ---: |
| math | 3 | 2 | 1 |
| phys | 0 | 4 | 1 |
| chem | 0 | 0 | 3 |


$X_{2,3}$
(periods 2-3)

| Field | math | phys chem biol |  |  |
| :--- | :--- | :--- | :--- | :--- |
| math | 5 | 3 | 2 | 1 |
| phys | 0 | 4 | 2 | 1 |
| chem | 0 | 2 | 4 | 3 |

$X_{3,3}$
(periods 3-3)

| Field | math phys | chem bikl |  |  |
| :--- | :---: | :---: | :---: | ---: |
| math | 4 | 2 | 1 | 1 |
| phys | 0 | 4 | 1 | 2 |
| chem | 0 | 0 | 1 | 3 |
| biol | 0 | 0 | 1 | 2 |

## Final demand

$Y_{1}$
(periods 1)

$\mathrm{Y}_{2}$
(perlods 2)

| 1 |
| :--- |
| 4 |
| 4 |

$Y_{3}$
(periods 3)

| 0 |
| :--- |
| 2 |
| 4 |
| 5 |

Employment and expenditures
period 1

|  |  | Field | math phys | chem Total |  |
| :--- | :--- | :--- | :--- | :--- | ---: |
| $\mathrm{L}_{1}$ | Scientists | 15 | 12 | 12 | 39 |
| $\mathrm{C}_{1}$ | Cosis $(5)$ | 150 | 250 | 100 | 500 |

period 2

|  |  | Field | math phys | chem | Total |
| :--- | :--- | ---: | ---: | ---: | ---: |
| $\mathrm{L}_{2}$ | Scientists | 15 | 10 | 14 | 39 |
| $\mathrm{C}_{2}$ | Cosis $(\$)$ | 150 | 250 | 150 | 550 |

period 3

|  | Field math phys chem blol |  |  |  |  | Total |
| :--- | :--- | ---: | ---: | ---: | ---: | ---: |
| $\mathrm{L}_{3}$ | Scientists | 14 | 10 | 10 | 8 | 42 |
| $\mathrm{C}_{3}$ | Costs $(\$)$ | 150 | 200 | 130 | 120 | 600 |

## The Citation Flow Tables

Table 2.2

| time ${ }^{\text {a }}$ fields |  |  | period 1 |  |  | period 2 |  |  | period 3 |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  |  |  | math | phys | chem | math | phys | chem | math | phys | chem | biol | final | $\begin{aligned} & \text { total } \\ & \text { output } \end{aligned}$ |
|  |  | 5 | 1 | 2 | 3 | 4 | 5 | 6 | $\overline{7}$ |  | 9 | 10 |  |  |
| period 1 | math | 1 | $x_{1,1}$ | $x_{1,2}$ | ${ }^{1,3}$ | $x_{1,4}$ | ${ }_{1.5}$ | $x_{1,6}$ | ${ }^{1,7}$ | ${ }_{1.8}$ | $x_{1,9}$ | $x_{1,10}$ | $Y_{1}$ | $\overline{X_{1}}$ |
|  | phys | 2 | $x_{2,1}$ | $x_{2,2}$ | $x_{2,3}$ | $x_{2,4}$ | $x_{2,5}$ | $x_{2,6}$ | $x_{2,7}$ | $x_{2,8}$ | $x_{2,9}$ | $x_{2,10}$ | $Y_{2}$ | $X_{2}$ |
|  | chem | 3 | $x_{3,1}$ | $x_{3,2}$ | $x_{3,3}$ | $x_{3,4}$ | $x_{3,5}$ | $x_{3,6}$ | $x_{3 .}$ | $x_{3.8}$ | $x_{3,9}$ | $x_{3,10}$ | $Y_{3}$ | $X_{3}$ |
|  | math | 456 | 0 | 0 | 0 | ${ }^{4,4}$ | $x_{4,5}$ | ${ }^{\text {4,6 }}$ | $x_{4,7}$ | ${ }^{4,3}$ | $x_{4,9}$ | $x_{4,10}$ | $Y_{4}$$Y_{5}$$Y_{6}$ | $X_{4}$ <br> $X_{5}$ <br> $X_{6}$ |
| period 2 | phys |  | 0 | 0 | 0 | $x_{5,4}$ | $x_{5,5}$ | ${ }^{5,6}$ | $x_{5,7}$ | $x_{5,8}$ | $x_{5,9}$ | $x_{5,1}$ |  |  |
|  | chern |  | 0 | 0 | 0 | $x_{6.4}$ | $x_{6,5}$ | $x_{6,6}$ | $x_{6,7}$ | $x_{6,8}$ | $x_{6,9}$ | $x_{6,10}$ |  |  |
| period 3 | math <br> phys <br> chem <br> biol |  | 0 | 0 | 0 | 0 | 0 | 0 | $x_{7, T}$ | $x_{7,8}$ | $x_{7,9}$ | $x_{7,10}$ | $Y_{7}$ | $\begin{aligned} & \hline X_{7} \\ & X_{8} \\ & X_{9} \\ & X_{10} \\ & \hline \end{aligned}$ |
|  |  | 8 | 0 | 0 | 0 | - | 0 | 0 | $x_{8,7}$ | $x_{8,3}$ | $x_{8,9}$ | $x_{8,10}$ | $Y_{8}$ |  |
|  |  | 9 | 0 | 0 | 0 | 0 | 0 | 0 | $x_{9,7}$ | $x_{9,8}$ | $x_{9,9}$ | $x_{9,10}$ | $Y_{9}$ |  |
|  |  | 10 | 0 | 0 | 0 | 0 | 0 | 0 |  |  |  |  |  |  |
| scientists <br> 5 Costs |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|  |  |  | $\begin{aligned} & \hline L_{1} \\ & C_{1} \\ & \hline \end{aligned}$ | $\begin{array}{l\|} \hline L_{2} \\ C_{2} \\ \hline \end{array}$ | $L_{3}$ | $L_{4}$ | $L_{5}$ | $L_{6}$ | $L_{7}$ | $L_{8}$ | $L_{9}$ | $L_{10}$ | $\begin{aligned} & \mathrm{L} \\ & \mathrm{C} \\ & \hline \end{aligned}$ |  |
|  |  |  | $\mathrm{C}_{3}$ |  | $C_{4}$ | $\mathrm{C}_{5}$ | $\mathrm{C}_{6}$ | C. | $\mathrm{C}_{8}$ | $\mathrm{C}_{9}$ | $C_{10}$ |  |  |  |

Table 2.3


## The Structural (Direct Requirements) Tables

Table 2.4

| time |  |  | period 1 |  |  | period 2 |  |  | period 3 |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | fields |  | main | phys | chem | math | phys | chem | math | phys | chem | biol |
|  |  | 5 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| period 1 | math <br> phys <br> chem | $\begin{aligned} & \hline 1 \\ & 2 \\ & 3 \end{aligned}$ | $\begin{aligned} & a_{1,1} \\ & a_{2,1} \\ & a_{3,1} \end{aligned}$ | $\begin{aligned} & a_{1,2} \\ & a_{2,2} \\ & a_{3,2} \end{aligned}$ | $\begin{aligned} & a_{1,3} \\ & a_{2,3} \\ & a_{3,3} \end{aligned}$ | $\begin{aligned} & a_{1,4} \\ & a_{2,4} \\ & a_{3,4} \end{aligned}$ | $\begin{aligned} & a_{1,5} \\ & a_{2,5} \\ & a_{3,5} \end{aligned}$ | $\begin{aligned} & a_{1,6} \\ & a_{2,6} \\ & a_{3,6} \end{aligned}$ | $\begin{aligned} & a_{1,7} \\ & a_{2,7} \\ & a_{3,7} \end{aligned}$ | $\begin{aligned} & a_{1,8} \\ & a_{2,8} \\ & a_{3,8} \end{aligned}$ | $\begin{aligned} & a_{1,9} \\ & a_{2,9} \\ & a_{3,9} \end{aligned}$ | $\begin{aligned} & a_{i, 10} \\ & a_{2,10} \\ & a_{3,10} \end{aligned}$ |
| period 2 | math <br> phys <br> chem | 4 5 6 | $\begin{aligned} & \hline 0 \\ & 0 \\ & 0 \end{aligned}$ | $\begin{aligned} & \hline 0 \\ & 0 \\ & 0 \end{aligned}$ | $\begin{aligned} & 0 \\ & 0 \\ & 0 \\ & 0 \end{aligned}$ | $\begin{aligned} & a_{4,4} \\ & a_{5,4} \\ & a_{6,4} \\ & \hline \end{aligned}$ | $\begin{aligned} & a_{4,5} \\ & a_{5,5} \\ & a_{6,5} \end{aligned}$ | $\begin{aligned} & a_{4,6} \\ & a_{5,6} \\ & a_{6,6} \end{aligned}$ | $\begin{aligned} & a_{4,7} \\ & a_{5,7} \\ & a_{6,7} \\ & \hline \end{aligned}$ | $\begin{aligned} & a_{4,8} \\ & a_{5,8} \\ & a_{6.8} \\ & \hline \end{aligned}$ | $\begin{aligned} & a_{4,9} \\ & a_{5,9} \\ & a_{6,9} \\ & \hline \end{aligned}$ | $\begin{aligned} & a_{4,10} \\ & a_{5,10} \\ & a_{6,10} \end{aligned}$ |
| period 3 | math <br> phys <br> chem <br> biol | $\begin{gathered} \hline 7 \\ 8 \\ 9 \\ 10 \\ \hline \end{gathered}$ | $\begin{aligned} & \hline 0 \\ & 0 \\ & 0 \\ & 0 \end{aligned}$ | $\begin{aligned} & \hline 0 \\ & 0 \\ & 0 \\ & 0 \end{aligned}$ | $\begin{aligned} & \hline 0 \\ & 0 \\ & 0 \\ & 0 \\ & \hline \end{aligned}$ | $\begin{aligned} & \hline 0 \\ & 0 \\ & 0 \\ & 0 \end{aligned}$ | $\begin{aligned} & \hline 0 \\ & 0 \\ & 0 \\ & 0 \end{aligned}$ | $\begin{aligned} & \hline 0 \\ & 0 \\ & 0 \\ & 0 \\ & \hline \end{aligned}$ | $\begin{gathered} a_{7,7} \\ a_{8,7} \\ a_{9,7} \\ a_{10,7} \end{gathered}$ | $\begin{gathered} a_{7,8} \\ a_{9,8} \\ a_{9,8} \\ a_{10,8} \end{gathered}$ | $\begin{gathered} a_{7,9} \\ a_{8,9} \\ a_{9,9} \\ a_{10,9} \\ \hline \end{gathered}$ | $\begin{gathered} a_{7,10} \\ a_{\mathbf{3 , 1 0}} \\ a_{9,10} \\ a_{10,10} \end{gathered}$ |
| $\begin{aligned} & \text { scientists } \\ & \text { \$ Costs } \end{aligned}$ |  | 1 $c$ | 1 $l_{1}$ $c_{1}$ | $l_{2}$ $c_{2}$ | $l_{3}$ $c_{3}$ | $l_{4}$ $c_{4}$ | $l_{5}$ <br> $c_{5}$ | $l_{6}$ $c_{6}$ | $1-$ $c_{-}$ | $l_{8}$ $c_{3}$ | $l_{9}$ $c_{9}$ | $l_{10}$ $c_{10}$ |

Table 2.5


## The Total (Direct \& Indirect) Requirement per Citation Delivered to Final Demand

Table 2.6

| time |  |  | period 1 |  |  | period 2 |  |  | period 3 |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | fields |  | math | phys | chem | math | phys | chem | math | phys | chem | biol |
|  |  | $s$ | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| period 1 | math | 1 | 1.18 | 0.12 | 0.10 | 0.30 | 0.36 | 0.25 | 0.97 | 1.26 | 1.11 | 1.62 |
|  | phys | 2 | 0.00 | 1.20 | 0.09 | 0.08 | 0.47 | 0.31 | 0.09 | 1.08 | 1.07 | 1.38 |
|  | chem | 3 | 0.00 | 0.00 | 1.23 | 0.00 | 0.11 | 0.38 | 0.00 | 0.49 | 0.84 | 1.20 |
| period 2 | math | 4 | 0.00 | 0.00 | 0.00 | 1.19 | 0.18 | 0.21 | 1.48 | 1.54 | 1.18 | 1.69 |
|  | phys | 5 | 0.00 | 0.00 | 0.00 | 0.00 | 1.31 | 0.28 | 0.00 | 1.16 | 0.87 | 1.18 |
|  | chem | 6 | 0.00 | 0.00 | 0.00 | . 0.00 | 0.09 | 1.23 | 0.00 | 0.56 | 1.00 | 1.32 |
| period 3 | math | 7 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 2.00 | 0.80 | 0.52 | 0.86 |
|  | phys | 8 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1.80 | 0.37 | 0.78 |
|  | chem | 9 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1.23 | 0.62 |
|  | biol | 10 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.21 | 1.44 |

## Output, Employment and Cost Requirements

Table 2.7

|  |  |  | Final | requirements |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| time | feld | 5 | demand | output | scientists | expenditures |
| period 1 | math | 1 | 1 | 20 | 15 | 150 |
|  | phys | 2 | 6 | 24 | 12 | 250 |
|  | chem | 3 | 3 | 16 | 12 | 100 |
| period 2 | math | 4 | 1 | 19 | 15 | 150 |
|  | phys | 5 | 4 | 18 | 10 | 250 |
|  | chem | 6 | 4 | 17 | 14 | 150 |
| period 3 | math | 7 | 0 | 8 | 14 | 150 |
|  | phys | 8 | 2 | 9 | 10 | 200 |
|  | chem | 9 | 4 | 8 | 10 | 130 |
|  | biol | 10 | 5 | 8 | 8 | -120 |

# The Structure of Innovation and its Adoption in the Italian Economy (1981-85) 

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# Xth WORLD INPUT-OUTPUT TECHNIQUES CONFERENCE MARCH 28 - APRIL 2, 1993, SÉVILLE, SPAIN 


#### Abstract

An "innovation matrix" is established from a recent ISTAT/CNR survey of. innovation. After specifying the particularity of an innovation matrix in comparison with other flow matrices, it is shown that the innovation matrix is asymmetrical and clustered in parts of the economic space. The structure of the innovation matrix is similar to that of the domestic and import requirement matrices, but not the capital flow matrix. Strong correlations indicate the usefulness of using input-output analysis for innovation and suggest furure examinations of nossible causal relationships.


## 1. Introduction

Innovation is a new way of doing things. As a new or improved product or process, an innovation can be analyzed as the setting up of a new production function (Schumpeter, 1939). For this reason, economic analysis in general, and input-output in particular, have mainly considered innovation as external to the economic system.

It may therefore appear paradoxical that we suggest that innovation has a "structure." Furthermore, it may appear curious to use input-output analysis - a tool most adapted to revealing stable structures and systems - in order to analyze this volatile and disruptive factor called innovation. Yet, in this paper, we will try to show that inputoutput analysis is an appropriate method for the study of innovation: its location in economic space also has a structure.

The central measurement problem is how to fit the "new" - innovation - into the categories of the "old" economic structures. By limiting our goals to mapping where in the Chris DeBresson, University of Quebec in Montreal, C.P. 6192, Suc "A" Montreal (Quebec) Canada H3C 4R2. This work, in particular sections 2 to 5 , was performed while at Concordia University. I thank the Fonds de création et diAide aux Chercheurs du Quéhec for its support. Giorgio Sirilli, Istituto di Studi sulla Ricerche e Documentazionc Scientifica, Consiglio Nazionale delle Ricerca. Xiaoping $H u \&$ Fung Kwan Luk. Center for Research on the Developinent of Industry \& Technology. Montreal. We want to thank Anne P. Carter, Stephen Klepper, F. Mike Scherer, Wassily Leontici. Faye Duchin. Andras Brody. Danicle Archibugi, Jérome Allaire, Pierre Mohnen and Rioberto Simonetti for comments and suggestions. although we have not been able to answe: all of their questions.
old economic structures innovative activity arises, we reduce the violence done to classifying the innovations to a minimum.

We know that firms are more diversified in terms of technological assets than output. Hence, there is even more of a temptation for input-output analyst of technology to use rectangular make/use matrices where lines are industries and columns are products, each industry producing and using an array of products. In this survey, however, we only have information about the economically most important innovation and its typical industry of use. We have therefore restricted ourselves to a square matrix, easier to manipulate.

Because input-output analysis can simultaneously take supply and demand factors into consideration, it enables us to supersede an overworked debate between "technology push" and "demand pull" (DeBresson, 1990). We will show that an "innovation matrix" has a clear pattern in relation to the table of economic activity; in particular, the "market profile" (or output coefficients) of the supply vectors of both matrices have similar structures.

Our study of innovation in Italy was made possible because its central statistical office carried out a compulsory survey explicitly designed to build such a matrix (ISTAT, 1990). Using a short questionnaire, 30,000 manufacturing firms (with more than 20 employees) were surveyed; 24,000 responded and 16,000 stated that they had introduced new or improved products or processes between 1981 and 1985. This population was then divided into two groups. The first, a more highly innovative group, was surveyed by interview; this yielded 2,701 respondents, who identified their economically most important innovation and indicated the most typical user industry, thus enabling us to build an innovation supplier-user matrix. For all respondant firms, we have a general sector of use (see Table 5). The findings can be tested for sensitivity of the measurement, as each innovation can be weighed by degree of novelty, share in the total sales or exports of the respondant.

The new findings in this paper can largely be attributed to a new set of systematic empirical observations. The higher level of resolution reveals marked patterns. If one considers three normal scientific stages - empirical measurement, pattern recognition, and then theory building and causal explanation - this paper remains at the second stage of pattern recognition. We want to convince researchers that there is a well characterized
phenomenon that requires analysis and theoretical examination. We do not attempt any causal analysis of these patterns here, although these correlations suggest hypotheses for future research.

Innovation surveys, like any industrial survey administered by central statistical offices, are surveys not only of innovation in the Schumpeterian sense, but also of its adoption. The survey thus captures both the setting up of new production functions as well as firm level innovation in a more modest sense, e.g. the commercial application of an idea that is new to a firm, but not necessarily new to world industry. From the perspective of the firm, innovation is only the commercial application of a new idea, and it cannot always tell ex ante whether its private innovation is new to the world. Many other firms are innovating simultaneously, and only the others' imitation will decide ex post if its private innovation was actually a bona fide creation, one new to the world and disruptive of the old ways of doing things. The data we are analyzing here are therefore about both innovation and its adoption. In order to minimize measurement problems and evaluate the sensitivity of our analysis to measurement, we have weighted innovations according to their degree of novelty and share they represent in the firm's sales and exports and checked all analyses with this weighted indicator. We have also performed the analysis on the subset of firms that claimed world first innovations.

Because we are also dealing with adoption of various innovations in this paper, there are reasons to expect the location and adoption of innovation to be directed by existing economic relations. But this is not to say that bona fide innovation (world firsts) may not also be affected by the economic environment. There is a well known continuum between imitation and modification, adoption and adaptation, straightforward adoption and re-innovation. Technological knowledge is cumulative, and there are no clear border lines between imitation and creation. Because innovation is a re-combination of factors and utilities, no individual element need be new as long as the combination is new. Incrementalism can therefore lead to qualitative change, and technical evolution can make leaps; the gradual improvement of the crankshaft, from at least the 9th century, leading to the birth of machinery in the 15th century is a case in point. It is therefore not impossible, as we shall see, that what is true of the adoption of innovation may also be true of the creation of the innovation: pre-existing economic relations may influence the locus of creation of new techniques.

Furthermore, Schumpeter focused and encouraged economists to deal mainly with substitute and radical innovations, and minimized the importance of complementary innovations within a system of interdependence. Technique, however, is at the root of economic interdependence and technical systems at the root of the concept of complements and substitute in consumer theory. No innovation stands alone without its auxiliary and complementary innovations. Techniques, and innovation, always come as part of systems. In our survey, radical substitute innovations are probably less frequent than complements, and therefore we should expect interdependence between innovations. Inputoutput techniques are ideally suited to analyze such interdependence.

## 2. What is an Innovation Matrix?

An innovation matrix is a standard square matrix in which the supplier industries of the firm make up the rows and the typical user industries of each innovation the columns. ${ }^{1}$ The frequency in each entry tells us the number of times a firm from industry i ha supplied that firm's economically most important innovation to a firm in industry $\mathbf{j}$.
(Table 1 approximately here)

The usefuiness of building a supplier-user innovation matrix derives from a recurrent finding of innovation case studies: a user - in particular the first user of an innovation - is as important to the generation of new products and processes as suppliers (von Hippel, 1989; Teubal, 1987). In the field of innovation studies, this universally accepted finding is equivalent to Alfred Marshall's insistence that both the supply and the demand curves of the market "scissors" be considered.

By definition, each innovation occurs only once for the firm; the change is more or less irreversible. (We are observing a phenomenon similar to a fixed investment inasmuch as the action is only taken once.) An innovation is therefore an indicator of the level of technological knowledge, and the innovation matrix is a fund matrix, but of a particular kind. Whereas an equipment stock will depreciate, a fund of technical knowledge may not automatically do so (DeBresson. 1990). Technological knowledge is cumulative, so that most prior knowledge will be incorporated and subsumed into new knowledge; some inventions may make some old knowledge even more valuable. Drawing on the fund of knowledge is more likely to increase than deplete it. Nor will the sale of a process to a competitor deplete the firm's own fund, which may actually increase because technological
knowledge is not an alienable or excludable good. In these respects an innovation matrix represents a very peculiar type of fund matrix.

A radical innovation could eventually create a new linkage between two industries (i.e. fill up an empty matrix cell) or even a whole new indsutry; but it would take a long time before this would show up in an input-output table. The adoption of the innovation will eventually affect the input coefficients. Theoretically, each innovation could be described by a corresponding vector of input coefficients in physical quantities reflecting its associated factor proportions. As an innovation diffuses in the industry and replaces previous practices, the physical quantity input coefficients of that industry will change. But we do not have information on the input coefficients of each innovation, and this analysis has not been done. Therefore, none of the likely effects of the innovation adoption on the input-output structure can be evaluated.

Ir. this paper we are concerned not with the effect of technical change on the economy, but the reverse: the effect of the economy on the patterns of technical change. In our study, the innovation matrix only maps the occurrence of the supply and use of an innovation, i.e the economic breeding grounds of creative entrepreneurial activity and its adoption not its economic impact.

There are many problems of measurement and classification in trying to map innovation in the economic space. The temptations offered by the versatile powers of matrix analysis must be resisted, temporarily at least. We have to make sure what and how we are measuring. A radical technological innovation such as solid state semiconductors electronics hardly fit into business machines or telecommunation industries in which it was classified for years. Squeezing new technologies into the categories of the old, therefore, pinches. But if we limit ourselves to identify where in the ofd economic landscape the new techniques start being used, we are not forcing reality. The new production functions are no doubt carriers, if and when they are adopted, of future economic structures - but this is another research topic.

## 3. Patterns

In this paper we establish the pattern of the innovation matrix and compare it with the total, domestic. import requirement and capital flow matrices of Italy in 1982 (ISTAT, 1987). In order to highlight the patterns, we calculated a transition (or
conditionnal probability) matrix, where the size of the supply vectors are normalized by dividing each cell by the line total of each supply vector. This gives us the output coefficient matrix, sometimes called the "marketing profile." In Graph 1, the matrix is on the horizontal plane and the percentage of the supply of innovation by an industry to another is displayed on the vertical axis; in Graph 2, the vertical axis displays the transition supply vectors of the total requirement matrix.

## (Graphs 1 \& 2 approximately here)

In Table 1, where the first line of each cell lists the flows of goods and services, the second capital flow, and the third innovation frequencies. Already it is apparent that innovation is often absent when there is exchange of goods and equipment: this indicates that innovation is clustered in only part of the economic table. The clustering of innovation is also reflected by the smaller number of cells having high values in the third line. In most cases, one would not expect much innovation if there is no economic activity at all. Those radical innovations that create new economic markets from scratch are exception. In Table 1, in only 4 cells are there some innovations without flows of goods or equipment. At the disaggregated level, only 30 cells show that some innovation exist when goods and services flows did not exist at the 100 million lires level.

In order to confirm Schumpeter's hypothesis that innovation clusters in only part of the economic space (Schumpeter, 1939; DeBresson, 1989), we compared the density indices

where $z_{i j}$ is the linkage between the supply sector $i$ and the user sector $j$ in the respective matrices and $N$ is the total number of possible cells. If the Italian case is consistent with Schumpeter's contention we should find that: $D_{i}<D_{10}$. In all cases, the density of the innovation matrix is lower than the other matrices. Innovation, either defined in a strict Schumpeterian or in a broader sense, is clustered in only part of the economic space.

It should be noted that the Italian domestic requirement input-ouput matrices themselves have a low density; what domestic flows exist are highly concentrated. A medium size and relatively open economy need not have all inter-industrial linkages
domestically and tends to be more specialized than a large country. Innovation will then be clustered within this restricted set of economic linkages. The question is: in which parts of the economic space?

## (Table 2 approximately here)

## 4. The Shape and Location of the Innovation Clusters

A characteristic of the Italian innovation system is its low level of integration. This can be measured by a directed graph analysis: to any sub-matrix form corresponds one directed graph and one only - there is a bijection between matrix forms and directed graphs (see appendix 1). In a directed graph, the "summet" corresponds to the industry which supplies or uses innovation, and the "arc" between two summets corresponds to the number of innovation linkages (the matrix cell value) between two summets. At any level of aggregation - whichever measure of innovation one uses(see appendix 2), and for a wide range of minimum arc values - the degree of integration in the innovation clusters is modest. In reference to the different types of clusters (described in Appendix 1), there are only clusters of the third order; i.e. agglomerations. In all cases, the consumer, construction and automobile industries remain the primary first users of innovation.

If one considers a level of innovative interaction that excludes low levels of arcs (which could be considered as random occurrences and statistical noise) whitout, howver, loosing a higher order graph, the Italian national innovation system appears to be constituted of two distinct and separate sub-systems: a simple innovative agglomeration and a non-standard tree, with weak links between them.
(Graph 3 approximately here)

The primary innovative agglomeration is formed by innovation clustering around final demand goods, be it by the consumer and construction (Graph 3). Many industries supply innovation to these three main users, some of them to all. This cluster accounts for the largest share of innovations in the Italian system.

The second innovative cluster, a non-standard tree (second also in number of industries and innovative interactions) is in producer goods around the chemical, metal
products, mechanical machinery, and automobile industries (Graph 4). This cluster of innovative industries accounts for a much smaller share of innovations in Italy
(Graph 4 approximately here)

The producer good innovation cluster has a weaker level of internal integration than that in the consumer goods in 1981-1985. The two clusters are only weakly related by a few nodal industries: machinery, metal products, electrical and electronic and chemical innovations. These are the only nodal industries. If we weight the importance of the innovations in terms of their contribution to the sales of the firm, or the contribution of the innovations to the global competitiveness of the Italian economy in terms of exports, the two main clusters are slightly more closely related.

In summary, the innovation system in Italy is more heavily oriented towards final consumer goods than to capital goods or other producer goods. This may explain why a modest amount of well-focused technology, much of it imported, has contributed considerably to economic growth and benefits to the country. Also, the lack of integration may be associated with the flexibility of the Italian industrial system.

## 5. The Main Suppliers and Users of Innovation in Italy

In order to have a clear sense of the contents of the disaggregated innovation matrix, it is useful to look sequentially at the main suppliers of innovation and then the first users (Tables $3 \& 4$ ).
(Tables $3 \& 4$ approximately here).

In Table 3, we ranked supplying industries first by the importance of the forward linkages (i.e. number of user industries they supplied (column 3)) and second by only the total number of innovations (column 1). In Table 4, we do the same for the user industries. As one would expect of a developed country, the main suppliers of innovation are producer goods industries, and in particular. fixed capital goods. The metal products, industrial chemicals and other chemicals, machinery and plastic products industries were major suppliers of innovations. Each of these industries supplies innovations to many industries, and in significant quantities (more than 100 innovations, or $3.7 \%$ of the total
supply of innovation). The ten largest supplying industries account for $40 \%$ of all innovations supplied; there is therefore some concentration in the supply of innovation.

The main users are those economic activities that focus the clustering of innovation in Italy. Among these, three dominate: the final consumer (family consumption), construction and the automobile industry. The consumers (or families) are supplied with innovations by many different industries: drugs, wood furniture, metal products, clothing, plastic products, electrical appliances, and many other industries. The automobile industry is supplied with innovation by itself, plastic products, electronic equipment, industrial machinery, metal products and other industries. From the point of view of the quantity of innovation used (but not number of backward innovative linkages), the construction industry was the second largest user of innovation in Italy during that period. From Table 4, it appears that the use of innovation is more concentrated than the supply of innovation. The first two economic activities - final consumption and automobiles - alone account for close to $30 \%$ of the total use of innovations; $68 \%$ of all use of innovation is concentrated in ten industries.

The above analysis was performed on 2,701 of the most innovative firms (and for their economically most important innovations), and may or may not be representative of the whole innovation survey of over 8,220 firms. For the whole survey, however, we do possess some very aggregated indication of innovation use: all respondents indicated the sectoral "economic destination" for which the technological innovations had been produced (e.g. final consumer goods, intermediate goods and components, finished capital goods, services to enterprises). These data enabled Cesaratto, Mangano and Sirilli (1988) to calculate a rectangular matrix (Table 5).
(Table 5 approximately here)

Table 5 confirms that intermediate ( $48.1 \%$ ) and final consumer demand ( $40.2 \%$ ) are more important destinations for Italian innovation than capital goods, which only accounts for $28 \%$. These general aggregated results are consistent with the more detailed matrix reported in this paper. "The direct fall-out from innovation on consumers is in any case a widespread phenomenon involving about $40 \%$ of firms" (ibid), in particular from wood furniture, footwear, clothing, metal products, textiles, food and chemical industries.

The Italian innovation system is an asymmetrical system: the most important users of innovation are most often not the same as the most important suppliers of innovation. Whereas producer sectors, in particular capital goods, are the most important suppliers of innovation, consumer sectors are the most important first users. The only exceptions are those industries that are important, to some extent, as both suppliers and users of innovation: mechanical machinery, chemicals, metal products and electrical and electronic industries. This result is consistent with those found in the United Kingdom and Canada (DeBresson \& Townsend. 1978; DeBresson et al., 1986). Thus only a few capital and producer goods industries (mechanical machinery, metal products and chemicals) are strategic from the point of view of generating new technology, and a few users (consumers. construction, automobiles) are strategic from the point of view of demand. As for the United Kingdom and Canada, one can thus understand why in Italy supporters of a "supply push" policy are not referring to the same set of facts as are supporters of a "demand pull" policy; both are right in different ways. We are in presence of a division of labor concerning the generation and use of new techniques and innovation.

## 6. Comparison of the Input-Output and Innovation Structure

Visually comparing Graph 1, the structure of innovation, with Graph 2, the structure of the total requirement matrix, casual empiricism suggests a similarity of structure. Checking this visual similarity statistically, we find a correlation of 836 ( $T$ test at the .0001 level of significance) between the two composite supply vectors. ${ }^{2}$ The Spearman Rank correlation is .58 . If we take only the subset of firms having "world first" innovations - thereby excluding most of the adoption phenomenon, we still find a . 49 correlation at the .01 level of significance between the two composite supply vectors.

A caveat related to the measurement problem is appropriate at this juncture. If we make the reasonnable assumption that the technical assets and activities are often more diversified than its product output, this similarity of structure is all the more surprising. However, in order to check the robustness of this similarity, it would be sueful to have information on the use sector of all innovations and not only the economically most important one. The we would have to comparte the innovation matrix structure with that of a "make/use" input-output matrix refecting the variety of outputs of the firms, and see if the similarity of structure still holds.
 emplojens and acesomic eetrity
(surober of fams)

| NLMBER OFEMPLOYESS | $\begin{aligned} & \text { Toul } \\ & \text { ineovming } \\ & \text { grox } \end{aligned}$ | Eeomomic cexination |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| ECOROMCACHVITY |  | $\begin{aligned} & \text { Fristad } \\ & \text { cocinera } \\ & \text { goods } \end{aligned}$ | Iftemedite gooda sad curnporex | $\begin{aligned} & \text { Fristred } \\ & \text { epond } \end{aligned}$ | $\begin{aligned} & \text { Semiese } \\ & \infty \\ & \hline \text { curprises } \end{aligned}$ |  |



| Emary, GAs, whiar <br> 1.4 Pecoleum | 19 | 11 | 15 | 3 | 2 | 3 |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Toul ${ }^{1.4}$ Pecoicum | 19 | 11 | 15 | 3 | 2 | 3 |
| 2 ERRAC.IVEMTRALS |  |  |  |  |  |  |
| 29 Mec | 148 | 16 | 123 | ${ }^{33}$ | ${ }_{27}^{2}$ | 16 |
| 24 Not meals, Mineris | 583 | 210 | 332 | 113 | 14 | 6 |
| IS Cumieas | 490 | 248 | 38. | 32 | 3 | 0 |
| $22^{-7}$ Pharmocauicals | 154 | -13 | 10 | , | 0 | 0 |
| 26 Symbeic dlores | 11 | 475 | 775 | 181 | 43 | 24 |
| Toul | 1,232 | 675 |  | 18. |  |  |
| 3 MATVFAC. METALS. <br> PRECSION NSTRNMETS |  |  |  |  |  |  |
| 3.1 Mexi prodecs | 1.051 | 308 | 611 | 309 | 63 | 16 |
| 12 Mecturical exginariag | 1.404 | 158 | 41 | 999 | 89 | 24 |
| 3.2 Machimen tooir | 287 | 18 | 91 | 222 | 16 | 7 |
| 3,28 Otho meckinery | 242 | 59 | 124 | 107 | 17 | 0 |
| 1.3 Oflee machinary 0 cuputas | 11 |  | 2 | 37 | 51 | 20 |
| 3.4 Ereric, Elemraie | 658 | 208 | 359 | 237 | 54 | 20 |
| 3.4.4 Elice mears incruar | 86 | 30 | 34 | 38 | 3 |  |
| 3.45 Radio-celevision intruin. | 111 | 34 | 72 | 29 | 10 |  |
| 3.4.6 Houscineld appliences | 82 | 60 | 24 | 14 | 3 | 6 |
| 15 Mocor vehicter and pros | 177 | 43 | 109 | 62 | 7 | 1 |
| 3.5. Mower metieler | 9 | 8 | 4 | 5 | 0 |  |
| 3.6 Ortber exaspor | 100 | 28 | 50 | 43 | 2 |  |
| 3.6.4 Acresperes indurny | 16 | 2 | 10 | ? | 2 | 0 |
| 1.7 Procision insoummer | 144 | 63 | 56 | ${ }_{1} 515$ | 229 | 73 |
| Total | 3.515 | 11 | 1,631 | 1.71 | 2 |  |
| 4 MUITFAC.: FOOD TEXTLES, <br> LEATHER OTHER |  |  |  |  |  |  |
| 4.1 Food | 319 | 277 | 72 | 34 | 1 | 2 |
| 4.1 Sugra Drakings | 212 | 180 | 47 | 19 | 45 | 10 |
| 4.2 Textiles | 714 | 303 | 425 | 66 | 6 | 3 |
| -4.4 Lenter | 132 | 53 | 86 | 13 48 | 13 | 5 |
| 4.5 Foorwery. Couting | 412 | 327 | 76 | 88 | 3 | 6 |
| 4.6 Hiood. Furmarts | 579 | 356 | 223 | 86 | 60 | 33 |
| 4.7 Paper. Primexing | 436 | 199 | 220 | 82 | 19 | 9 |
| 4.1 Rutber. Plasic | 477 | 190 | 324 | 18 | 12 | ) |
| 1.8.1 Tyers | 89 | 26 | 76 | 10 | 5 | . 6 |
| 4.9 Other mantacminas | 149 | 126 | $\begin{array}{r}37 \\ 1530\end{array}$ | 402 | 154 | 82 |
| Tocal | 3.424 | 20.1 | 1.530 | 402 | 15 | 8 |
| TOTA | 1.:300 | 3.308 | 3.95: | 2.300 | 428 | 182 |

For economists, the present results appeal to our common sense. They are also consistent with economic theory, which has related the orientation of innovative efforts with demand (Schmookler, 1966). In other words, the innovation of one supplier industry will likely be used in greater proportion by a user industry that consumes more of that suppliers output.

We performed, however, the same analysis again with the demand vector, putting the percentage supplied by each industry on the vertical axis: the correlation was .24 , and the resemblance of the two structures still existed, but was not quite as striking. This is consistent with previous tests, which show innovation patterns more regularly correlated with demand factors than with supply, although both must obviously be taken into account.

Let us now look at the substance of these similarities between the total requirement and innovation matrices: the importance of final demand of the consumer for most supplying industries (the line of "trees" in the back row) is common in both graphs; the diagonal of the intermediate exchange matrix is important in the two graphs (it represents self-supply of process innovation, perhaps internal to the firm itself); and a number of supplying industries that have a wide scope of forward linkages (such as chemicals, metal products and chemicals) also have a pervasive innovative effect on many user industries what may be called a "forward technological linkage." Although the existence of a linkage or its non-existence, as indicated by a zero value in a cell - of the two matrices correlate, the frequencies of the cells do not, as some industries do not have the same importance in both matrices.

Examining in more detail which components of the input-output have a similar structure to that of innovation and its adoption, we found that the domestic requirement matrix is highly correlated (. 80 at the 0.0001 level of significance) and the import requirement matrix somewhat less so (.68 at the 0.0001 level). The "pervasive" innovation supplying industries are not as well matched by import supply vectors.

If, however, we compare the innovation structure with the capital flow matrix (12 $x$ 23), ${ }^{3}$ there is weak correlation (.278 at the 0.0001 level). The suggestion by Schmookler and classical economists that technical change is oriented by capital formation is not confirmed with this cross-sectional snapshot (and would require time series data). The importance of final demand and the consumer for most suppliers of innovation in the Italian innovation system - in contrast to producer goods - is reflected in the lack of
similarity of structure of capital flows and innovation. Nevertheless, a similarity does remain: a number of supplying industries that have wide forward linkages in the capital flow matrix (such as metal products, machinery and chemicals) also have pervasive forward innovative linkages. Capital formation in Italy may affect foreign innovation through imports of capital goods more than domestic innovation.

The strong structural relationships between the supply vectors of the total requirement matrix of 1982 and the innovation matrix of 1981-5 holds with the 1985 input-output matrix - corresponding to the last year of the innovation survey. We performed a stepwise regression using all the supply vectors, and found mean $R^{2}$ for some 30 equations between . 74 and .90 with variance between . 14 and .31 , whatever set of two matrices we use. Whether we try to explain the innovation supply vectors with the goods supply vectors of 1982 or 1985 , or the reverse, the statistical results are very similar (appendix 3). In other words we are confronted with a very strong structural similarity - so strong that it is impossible to infer any direction of causality. We can interpret this in three ways: either the two phenomena are so intrinsically interlinked that it is impossible to seperate out the effects of each phenomenon on the other; or, both phenomena are affected by a third set of unspecified variables; or, a combination of the former.

## 7. Conclusion

In summary, the innovation supply and use matrix reveals a clear structure, but we will have to wait for the results of the next survey to see if this structure is stable. Innovation is clustered in part of the economic space, consistent with Schumpeter's assumptions. In Italy, at least during 1981-85, the main cluster is focused on final demand, automobiles and construction; a smaller cluster exists around producer and capital goods, but there are only a few weak links between the two clusters.

Two independent data sets - collected separately, with different goals in mind and using different methods - reveal similar structures, in particular of output coefficient structures. The innovation output coefficient matrix is similar to the corresponding total, domestic and import output requirement matrices; the capital flow matrix, however, is not similar. The recognition of this pattern in this large innovation survey suggests that, in Italy at least, there is some relationship between innovation patterns and economic exchanges. If this pattern reveals itself as specific to Italy then it might tell us something about this country; if this pattern is shared by other countries, we may be observing some strong relationship between innovation and other economic variables (or between both and a third set of variables) worth examining theoretically.

In this paper, we pointed only to the co-incidence of similar patterns and suggest that input-output analysis is the appropriate tool to reveal these structures and their similarities. We do not claim any causality of exchanges of goods on innovation patterns or the reverse; this requires other analyses. Whether or not one could establish such causality in the future and establish stochastic relationships between the two, however, would have wide implications for future survey sampling, forecasting, reduction of uncertainty, planning and dynamic modelling.

## Notes

[^0]2. The correlation is calculated between the string of supply vectors of innovation (in percentages) and output of goods and services. In Graphs 1 and 2 we have put on the vertical axis the percentages of the supply of an industry which is used by another industry. In other words the total of each supply vector is equal to $100 \%$. We checked that our statistical analysis was not sensitive to the use of percentage vectors. Selecting randomly $75 \%, 80 \%$, $90 \%$, or $95 \%$ of the observations in the stacked vector, the results were stable.
3. We thank ISTAT for supplying us with this unpublished data.

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## Appendix 1: The directed graph method of identifying clusters

At a very elementary level one can differentiate supplier-user interactions using simple set theory concepts. We can distinguish whether they are unidirectional, symmetrical (if $a-b$, then $b-a$ ), or transitive (if $a-b$, and $b-c$, then $a-c$ ). These simple notions enable us to distinguish extreme types of clusters. A first extreme type of cluster is when all industries are innovating with each other; we will call these clusters "cliques." Another type of cluster is when linkages are unidirectional; we will call these "trees." In between, we can define "agglomerations" or "complexes" as innovation clusters that have some symmetrical or transitive linkages. Of course there are innovative industries that are independently innovative and do not interact innovatively with any others; we call these "points of development" or "enclaves." The rank order of clusters (see list below) must be seen as an indicator of synergy and integration: the higher the level of cluster, the higher the suspected level of positive or negative synergy. (For a more extensive discussion of the mathematics, see Lemay and DeBresson, 1988.)

Let us just give the mathematical definitions of each of these directed graphs (or clusters). First, we have six elementary structures:

1. Development point: A summit is called a development point if and only if (iff) ( $i, i$ ) is an element of $D$ and for each $J=i,(i, j)$ and ( $j, i$ ) are not elements of $A$.
2. Innovative couple: A connex component $G^{\prime}=\left(S^{\prime}, A^{\prime}, D^{\prime}\right)$ of $G$ is called an innovative couple iff the cardinality of $S^{\prime}=2$ and the cardinality of $A^{\prime}=2$.
3. Standard tree: A connex component $G^{\prime}=\left(S^{\prime}, A^{\prime}, D^{\prime}\right)$ of $G$ is said to be a standard tree iff cardinality of $S^{\prime}=$ cardinality of $A^{\prime}-1$ and for every element of $S^{\prime}$, deg ${ }^{-}(i)<=1$
4. Non-standard tree: $A$ connex component $G^{\prime}=\left(S^{\prime}, A^{\prime}, D^{\prime}\right)$ of $G$ is said to be a non-standard tree iff cardinality of $S^{\prime}=$ cardinality of $A^{\prime}-1$ and for every element of $S^{\prime}$, $\operatorname{deg}^{-}(\mathrm{i})>1$.
5. Standard cycle: A connex component $G^{\prime}=\left(S^{\prime}, A^{\prime}, D^{\prime}\right)$ of $G$ is said to be a standard cycle iff for every element of $\mathrm{S}^{\prime}, \operatorname{deg}^{-}(i)=\operatorname{deg}^{+}(i)=1$
6. Non-standard cycle: A connex component $G^{\prime}=\left(S^{\prime}, A^{\prime}, D^{\prime}\right)$ of $G$ is said to be a standard cycle iff for all element of $S^{\prime}, \operatorname{deg}^{-}(i)+\operatorname{deg}^{+}(i)=2$ and there exists $i$ element of $S^{\prime}$ such that $\operatorname{deg}^{-}(i)=0$

From the six above elementary structures, it is also possible to define three composite structures, thus covering all possible structures:

1. Clique: A connex component $G^{\prime}=\left(S^{\prime}, A^{\prime}, D^{\prime}\right)$ of $G$, of an order superior to 2 , is said to be a clique iff for all $E=\left(S^{\prime \prime}, A^{\prime \prime}, D^{\prime \prime}\right)$ contained in $G^{\prime}$, cardinality of $S^{\prime \prime}=2 \Rightarrow E$ is an innovative couple
2. A technological complex: A connex component $G^{\prime}=\left(S^{\prime}, A^{\prime}, D^{\prime}\right)$ of $G$ is said to be a technological complex iff there exists a structure $E$ contained in $G^{\prime}$ that is an innovative couple, and there exists a structure $E^{\prime}$ of second order contained in $G^{\prime}$ that is not an innovative couple.
3. A simple agglomeration: A connex component $G^{\prime}=\left(S^{\prime}, A^{\prime}, D^{\prime}\right)$ of $G$ is said to be a simple agglomeration iff $G^{\prime}$ is not an elementary structure and $G^{\prime}$ contains no innovative couple.

These 9 types of clusters constitute a complete bijection with different types of sub-matrix forms, so that, given a specification of minimum arc value, a computer algorithm is capable of rigorously identifying a di-graph from a matrix.

A full mathematical definition of the directed graphs corresponding to these different clusters (simple or combined forms) and the computer algorithm are to be found in Lemay and DeBresson'(1988). The programme can be requested from the first author.

|  | Minimum Value | Arc | Number of | Ares | Number of Industries |
| :---: | :---: | :---: | :---: | :---: | :---: |
| Frequency | 1 |  | 769 |  | 157 |
|  | 2 |  | 347 |  | 123 |
|  | 3 |  | 329 |  | 115 |
|  | 4 |  | 167 |  |  |
|  | 5 |  | 137 |  |  |
|  | 6 |  | 107 |  | 85 |
|  | 7 |  | 84 |  | 76 |
|  | 87 |  | 1 |  |  |
|  | 87 |  | 1 |  | 2 |
| Weighted |  |  |  |  |  |
| by sales* | 1 |  | 731 |  | 153 |
|  | 6 |  | 379 |  | ...... |
|  | 11 |  | 196 |  | 109 |
|  | 16 |  | 138 |  | 93 |
|  | 18 |  | 112 |  | 83 |
|  | 19 |  | 102 |  | 77 |
|  |  |  |  |  |  |
|  | 329 |  | 1 |  | 2 |
| by exports | 1 |  | 606 |  | 151 |
|  | 11 |  | 142 |  | 83 |
|  | 12 |  | 134 |  | 82 |
|  | 13 |  | 121 |  | 79 |
|  | 153 |  | ..... |  | $\cdots$ |

* excluding 38 firms that found the contribution of innovation to sales impossible to estimate
"* excluding 32 arcs from firms that reported it was impossible to estimate the share of innovation in their exports and 131 arcs from firms that had no exports at all

| DEPENDENT VARIABLE: INNOVATION VECTORS INDEPENDENT VARIABLE: INPUT-OUTPUT VECTORS |  |  |  |  |  | INPUT-OUTPUT VECTORS INNOVATON VECTORS |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  |  |  |  |  |  |  |  |  |
|  |  |  |  | UARE |  | RANK | R-SQUA |  |
| sector | 1982 | 1985 | 1982 | 1985 | 1982 | 1985 | 1982 | 1985 |
| 1 | NA | NA | NA | NA | NA | NA | . 97 | . 58 |
| 2 | NA | NA | NA | NA | NA | NA | . 58 | 96 |
| 3 | NA | NA | NA | NA | NA | NA | . 99 | NA |
| 4 | NA | NA | NA | NA | NA | NA | NA | NA |
| 5 | NA | NA | NA | NA | NA | NA | NA | NA |
| 6 | NA | NA | NA | NA | NA | NA | NA | NA |
| 7 | 1 | 1 | . 99 | . 99 | 1 | 1 | . 99 | . 99 |
| 8 | NO | NO | . 90 | . 91 | NO | NO | . 88 | . 30 |
| 9 | NA | NA | NA | NA | NA | NA | . 98 | . 54 |
| 10 | NA | NA | NA | NA | NA | NA | . 92 | . 33 |
| 11 | NA | NA | NA | NA | NA | NA | . 37 | NA |
| 12 | NA | NA | NA | NA | NA | NA | NA | NA |
| 13 | NA | NA | NA | NA | NA | NA | NA | . 51 |
| 14 | 1 | 1 | . 97 | . 97 | 1 | 1 | . 71 | . 69 |
| 15 | 1 | 1 | . 97 | . 98 | 1 | 1 | 95 | . 94 |
| 16 | 1 | 1 | . 96 | . 97 | 1 | 1 | . 98 | . 98 |
| 17 | 1 | 2 | . 99 | . 99 | 1 | 2 | . 99 | . 91 |
| 18 | 1 | 1 | . 94 | . 95 | 1 | 1 | . 94 | 36 |
| 19 | 1 | 5 | . 99 | . 99 | 1 | 1 | . 91 | . 89 |
| 20 | 8 | NO | . 99 | . 99 | 1 | NO | . 93 | . 99 |
| 21 | 3 | NO | . 97 | . 96 | 1 | 4 | . 79 | . 94 |
| 22 | 1 | 1 | . 96 | . 95 | 2 | 1 | . 98 | . 92 |
| 23 | 1 | 1 | . 95 | . 96 | 1 | 1 | . 97 | . 94 |
| 24 | 1 | 1 | . 97 | . 99 | 1 | 1 | . 97 | . 89 |
| 25 | 1 | NO | . 66 | . 66 | NO | NO | . 95 | . 46 |
| 26 | 1 | 1 | . 98 | . 98 | 1 | 1 | . 98 | . 96 |
| 27 | 1 | 3 | . 89 | . 97 | 1 | 1 | . 85 | . 80 |
| 28 | 1 | 1 | . 65 | . 67 | 1 | 1 | . 65 | . 74 |
| 29 | 9 | NO | . 99 | . 99 | 1 | NO | . 99 | . 24 |
| 30 | 1 | 1 | . 99 | 99 | 2 | 7 | . 99 | . 99 |
| 31 | NA | NA | NA | NA | NA | NA | . 82 | NA |
| 32 | NA | NA | NA | NA | NA | NA | . 61 | NA |
| 33 | NO | NO | 97 | 99 | NO | NA | . 80 | NA |
| 34 | 1 | NO | 82 | . 83 | NA | NA | . 99 | . 98 |
| 35 | 1 | 2 | . 94 | . 95 | 1 | 2 | . 97 | . 96 |
| 36 | 1 | 3 | . 99 | . 99 | 3 | 2 | . 99 | . 99 |
| 37 | NO | NO | . 99 | . 99 | 2 | NO | . 99 | . 99 |
| 38 | 1 | 1 | . 95 | . 95 | 2 | 1 | . 99 | . 99 |
| 39 | 1 | 1 | . 99 | . 99 | NO | 7 | . 99 | . 99 |
| 40 | 2 | 2 | . 99 | . 99 | 1 | 1 | . 98 | . 97 |
| 41 | 1 | 1 | . 98 | . 98 | 1 | 1 | . 97 | . 95 |
| 42 | 1 | 1 | . 86 | . 97 | 1 | 1 | . 94 | 93 |
| 43 | NO | NO | . 99 | . 99 | 1 | 1 | . 99 | . 99 |

NA Not applicable because of 0 on one the two vectors either because of of true 0 values or because of absence of that sector in the innovation survey.
NO The corresponding vector does not appear in stepwise regression
Rank of corresponding supply vector


Table 2: Density indices for different matrices

| matrix <br> size | World Firsts | Innovation | Total <br> requirement | Domestic <br> requir. | Import <br> requir. | Capital flow |  |
| :--- | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| $43 \times 66$ | .072 | .11 | . | 48 | .46 | 26 |  |
| $12 \times 23$ | .43 |  |  | .70 |  |  |  |

Table 3 The 10 First Suppliers



GRAPH 1 : The Innovation Output Coefficient (100: sum of each supply vector)


GRAPH 2: The Output Coefficients of the Total Requiremer: Matrix


Graph 1: Final consumer innovative agglomeration (16 industries, 17 interactions)


Graph 2: Innovation Agglomeration in Producer Goods (14 industries; 15 interactions)

# Measurement of Technical Change in the Total Production System e $\cdot$ 

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#### Abstract

A general definition of production is given. It involves the inclusion of the production of human capital and of active human in the total production system. The total production system is represented by means of the dynamic input-output-model, generalized to include the production of heterogenous human capital and human time. The rate of change of the balanced rate of growth is suggested as a measure of overall technical change. It is a generalization of the traditional measure of technical change to the total production system. The rate decrease of the production price is suggested as a sectoral measure of technical progress. It is a generalization of the sectoral measure of technical change for wholly integrated sectors. The main results of an empirical application to the Finnish data in 1970,1980 and 1985 are given.


## 1 Introduction

Technical change, or change in total factor productivity, is normally measured by the difference between the growth rate of output and the weighted sum of the growth rates of productive inputs. If output is represented by the value added then only capital and labour are regarded as productive inputs, or as factors of production. On the other hand, also intermediate inputs can be treated as factors of production. In this case they have to be included in the value of output as well.

However, sectors do not benefit only from improvements in their own immediate production techniques but also from technical progress in sectors producing inputs for them. This fact is taken into account in a measure of technical change in which all the sectors contributing, directly or undirectly, to the final output of a sector are thought to be vertically integrated to that sector. This measure has been derived, in different ways, by Peterson (1979), Wolff (1985) and Cas \& Rymes (1991). All of them have also suggested different ways of treating also capital stock as a produced input.

Here we are going even further. Also human capital and active human time are treated as products. This is dictated by the inner logic of the definition of total production suggested here and not just by the opinion of this author. It also follows, directly from the definition of production, that the natural way of representing the total production system is the dynamic input-output model, modified to deal with long gestation and productive periods and generalized to include the production of human capital and of active human time.

Then the concept of technical change is generalized to the total production system defined in this paper. The rate of change of the balanced rate of growth, suggested here as the overall measure of technical change, is a generalization to the total production system of the traditional overall measure of technical change. Likewise the rate of change of the production price based on the generalized input-output dynamics, suggested here as the sectoral measure of technical change, is a generalization to the total production system of the sectoral measure for the wholly integrated sectors. A decrease in the production price, of course, signifies technical progress. The balanced rate of growth of the dynamic input-output model as such has been used as an indicator of the growth potential of an economy e.g. by Carter (1974).

Treating human capital as a product means, among other things, that the efficiency of producing educated human capital, i.e. the efficiency of the education system, is taken into account in the overall measure of technical change. Treating active human time as a product means, for instance, that the cost of free services used by persons producing labour of a given type are taken into account in the sectoral measures of technical change for the sectors utilizing labour of this type. This concerns also all the other costs: the production prices on which the sectoral measures are based include the ultimate production costs of all the materials, public services etc. used to bring about the product and not only what is paid for these inputs by the producers.

Since also human capital and active human time are produced within the production system the only primary input is the postponement in the usingup of different products tied up in the production process. This can be called "waiting" following Rymes (in Cas \& Rymes (1991)). The rate of balanced growth in the total production system, in the last analysis, measures the productivity of the nation, i.e. the efficiency of the nation in the utilization of its natural resources, the natural talents of its members included.

Because the generalized input-output dynamics cover the production of human capital and of active human time its empirical application requires data from a very large variety statistical sources. At the same time, it offers a natural systemizing framework for the social statistics, that part of social statistics that falls outside the national accounts proper included. The data requirements of the empirical application of the generalized dynamic input-output model are however not discussed in this paper. Information about them is available in Aulin-Ahmavaara (1992) and, in more detail, from the author. Neither is the method of calculating the balanced growth solution represented here. Descpriptions of it can be found in Aulin-Ahmavaara (1987) and Aulin-Ahmavaara \& Aulin (1992).

The empirical application represented in section 4 of this paper concerns Finnish data from the years 1970, 1975 and 1985. It shows that the Finnish economy is actually very close to the balanced growth path of the generalized dynamic input-output model. The main exceptions are the too small number of children as well as the too large number of persons in retirement when compared with the balanced growth path.

The empirical application also shows the decline in the overall productiv-
ity of the Finnish nation. The changes in the sectoral productivity measures, ie. the changes in the ultimate production costs are also discussed in some detail, mainly to demontrate the possibilities of the method suggested in this paper. The results concerning the Finnish economy may however be indicative of the development in the other welfare economies as well.

## 2 The Total Production System

### 2.1 The need for a redefinition of production

In a draft revision (UN(1991)) of the SNA recommendation economic production is defined as an activity carried out under the control and responsibility of an institutional unit that uses inputs of labour, capital, and goods and services to produce outputs of goods and services. In the last analysis it is of course the definitions of goods and services that delimit production in this case.

Goods are defined as physical objects whose ownership rights can be transferred from one institutional unit to another. Services again are heterogeneous outputs that can be ordered from other units and "typically consist of changes in the conditions of the consuming units realized by the activities of the producers at the demand of the consumers" (draft revision of the SNA).

There is a certain lack of consistency in the SNA definition of production. Services made by the households for themselves are excluded, although they can be used to subsitute private or government services. Labour is treated as a product when it is provided by one household to another to produce domestic services utilizing materials and equipment owned by the latter, but not when it is provided by a household to an enteprise to produce something utilizing equipment and materials owned by the enterprise. Human capital is not treated as a product although it is equally indispensable to the continuation of the production process as is physical capital. The goverment sector is not treated as a production sector in the same sense as the business sector; its intermediate inputs are included in final consumption.

The SNA definition actually does not give any general principle according to which the definition of production could be extended beyond the market
system proper. Here we will try to delimit production by giving the general features of the activities that are included.

### 2.2 Human capital and active human time as products

It is obvious that human beings are in one way or other needed in the production process. When human beings are involved in something they have to use their time, which will here be called active human time.

Accordingly in this study production is defined as follows:
Production is direct or undirect utilization of active human time to bring about something that can be used up or transformed into another form in a process utilizing active human time directly or undirectly.

This defines, fullowing the tradition iniated by Francois Quesnay (1694-1774), production as a circular process in which commodities are produced by means commodities. Still a definition of active human time is needed.

Active human time is any use of time by human beings who have passed their basic education and have not become unable to work.

And finally a product has to be distinguished from its intermediate phases:
A product is a result of the production process that is used either outside the unit that has produced it or outside the time unit during which it has been produced or to produce another unit of similar product.

From these definitions it is obvious that active human time is also a product. The time of persons in retirement because of incapability of work has been excluded since their time cannot any more be used to produce something that could be used elsewhere in the production process. (In actual practice also those in retirement because of age - however capable of working they meay still be - have to be excluded, since their working capabilities are not registered in national statistics.) The time of children and young people under compulsary basic education has been excluded for the same reason.

As to the time of the rest of the population it is a product no matter in which way it is used. Labour and leisure are only different uses of the same product, viz. active human time.

It follows from the definition of production that also that part of human capital which is created by raising children and by participating in education has to be regarded as a product. It is used up in the production of active human time. Also the intermediate phases of human capital are products because they are moved over to the next time period in order to be used in the production of subsequent phases of human capital.

Let it be emhasized that production as defined above does not include creation of human knowledge, although it includes the transfer of knowledge and skills called education.

Different kinds of human capital and of active human time are the only output of households they can use themselves. All the consumption of goods and services by them is used directly as an input in this production and not for instance as an input in the production of meals, or cleaning services or child care services for themselves. This follows from our definition of a product. In addition to this households, naturally, can also produce goods and services to be used by other units of production.

A problem of aggregation, which doesn't concern merely the production process of active human time, is to decide how the production units should defined and the length of the time unit chosen. The latter is discussed in Aulin-Ahmavaara (1990).

### 2.3 Total production system including human capital and active human time

A natural way of representing a production process as defined above is Leontief's (1953) dynamic input-output model. Production of labour was explicitly introduced to this model by Brody (1970). His model however includes the production of labour still on a relatively general level and does not include production of human capital as a separate product. A dynamic input-output model generalized to include the production of heterogeneous human capital and heterogeneous active human time (or labour) has been introduced and developed further in Aulin-Ahmavaara (1987), (1990), and (1991). The most comprehensive representation of its present state is given in Aulin-Ahmavaara
and Aulin (1992). In this section its main features will be delineated.
Two sets of essential time periods in the representation of the production process in time by means of a dynamic input output model are the gestation periods of units of output and the productive periods of units of input. They are defined as follows:

Gestation period $S_{j}$ of a unit of output of a production unit $j$ starts when the first unit of any input is involved in the production of this unit of output and ends when this unit of output is moved to the stocks of some other production unit.

Productive period $P_{i j}$ of a unit of input $i$ in a production unit $j$ starts when the delivery to which this unit of input belongs is first used in the production unit $j$, and it ends when the last unit of output in the production of which it is involved leaves the stocks of the production unit $j$.

A production unit can also use itself part of its own output. In this case the gestation period of a unit of output ends and its productive period starts when the unit of output is first involved in the production of another unit of output.

It is also possible that inputs belong to the stocks of a production unit for some time before they are actually used in the production. This possibility is here disregarded for the sake of simplicity. It has been taken into account in the formalism of Aulin-Ahmavaara (1990), where the definitions of the time periods connected with the dynamic input-output model as well as the significance of the choice of the basic interval of time of the model are discussed in more detail.

Both gestation periods and/or productive periods of some of the products inevitably exceed the length of the basic interval of time in the model, normally a year. As to the productive periods this concerns both physical capital and human capital. As to the gestation periods it concerns especially human capital, though to a lesser extent also physical capital. The units of human capital have the additional feature that they can outlive their productive periods, ie. become incapable of work. All this means that the coefficients of the model depend on the earlier path of the economy (see e.g. Aulin-Ahmavaara (1990 and 1991)).

When the balanced growth path of the generalized dynamic input-output model

$$
\begin{equation*}
x-A^{*} x=\lambda B^{*} x \tag{1}
\end{equation*}
$$

is calculated this dependence has to be taken into account. Here the asterisks are used to denote that part of the elements of the matrices are not ordinary input and stock coefficients. They have been modified, by utilizing special coefficients, to deal 1) with productive periods longer than a year and 2) with periods of retirement. In these special coefficients it possible to take into account that there are different routes to the same education and that there can be variation in the lentghs of the productive periods and periods of retirement of persons belonging to the same educational category. These coefficients as well as their derivation are represented in full detail in AulinAhmavaara (1990) and (1991).

The problem of gestation periods longer than a year can be solved by dividing the production of an output with long gestation period into phases and treating different phases as different products. See e.g. Aulin-Ahmavaara and Aulin (1992).

Both the matrix $A^{*}$ of input coefficients and the matrix $B^{*}$ of stock coefficients have the following structure in the generalized input-output dynamics:
$\left(\begin{array}{c|c|c}\text { GG } & \text { GE } & \text { GT } \\ \hline 0 & \text { EE } & \text { ET } \\ \hline \text { TG } & \text { TE } & \text { TT }\end{array}\right)$

Here
$G=$ the totality of sectors producing market or non-market goods and services outside the households. It includes also a sector producing foreign goods and services.
$E=$ the totality of sectors producing different types of human capital. Every person who has finished his basic education $1 E$ has formed a unit of simple human capital. It should be noted that he has this unit of simple human capital until his retirement or death. He can then participate in some other education say $i E$. When he has finished this education $i E$ he has produced a unit of human capital of type $i$ and has also this unit of human capital in his possession for the rest of his productive life, and so on.
$T=$ the totality sectors producing different types of active human time. Every person who has finished his basic education and has not retired produces human time of the type which matches his latest education. In this production all the units of human capital produced by him are used as capital equipment. He can use this active human time produced by him either in the production of goods and services, in the production of human capital of type $1 E$ by taking care of children, in the production of human capital of some type he does not posess as yet by participating in education, or in the production of active human time in the form of household work or leisure.

## 3 The Generalized Measures of Technical Change

The rate of balanced growth $\lambda$ associated with the empirical matrices of the dynamic input output model gives a measure of the growth potential of an economy utilizing the production technique represented by these matrices. This property of the dynamic input-output model has been utilized by e.g. Carter (1974) when studying the effects of changes in the technical coefficients on the growth potential of the U.S economy.

Here it is suggested that the rate of overall technical change of the total production system of an economy is measured by the rate of change $d \lambda / \lambda$ of the balanced rate of growth associated with it. The rate of sectoral technical change of a sector $i$ again is measured by the rate of change in its production price $d p_{i} / p_{i}$ caclulated from the dual of the balanced growth solution of the dynamic input-output model. A decrease in the production price, of course, means technical progress.

### 3.1 The generalized overall measure

In this section it will be shown that the overall measure suggested here is a generalization to the total production system of the traditional overall measure of technical change. The representation of the earlier measures in this section and in the next one follows rather closely the work of Wolff (1985). That representation offers a good basis for showing the formal similarity
between the measures suggested in this study and the measures suggested elsewhere.

Following symbols will be used, in addition, to those given in the previous sections:

$$
\begin{array}{ll}
X & \text { vector of gross output by sector } \\
Y & \text { = vector of final demand by sector } \\
l & \text { =vector of labor coefficients } \\
k & \text { = vector of capital stock coefficients } \\
p & \text { = vector of prices } \\
w & \text { = the uniform annual wage rate } \\
y & =p Y=\text { gross national product at current prices } \\
L & =l X=\text { total employment } \\
K & =k X=\text { total capital stock }
\end{array}
$$

All these variables refer to time $t$.
The standard overall measure of the rate of productivity growth is defined as

$$
\begin{equation*}
\rho=(p d Y-w d L-r d K) / y . \tag{2}
\end{equation*}
$$

Since the measurement of total factor productivity is based on the assumption of competitive equilibrium, a uniform wage rate $w$ as well as a uniform rate of profit $r$ can be assumed. The equilibrium price vector can then be computed from

$$
\begin{equation*}
p=(w l+r k)(I-A)^{-1} . \tag{3}
\end{equation*}
$$

Furthermore in the static input-output model

$$
\begin{equation*}
Y=(I-A) X \tag{4}
\end{equation*}
$$

The rate of aggregate total factor productivity can now (Wolf (ibid.) p.269) in view of (2)-(4) and of definitions of $L$ and $K$ be expressed as

$$
\begin{equation*}
\rho=-(p d A+w d l+r d k) X / y . \tag{5}
\end{equation*}
$$

On the other hand, multiplying both sides of equation (1) by the equilibrium price vector of the dynamic input-output model $p$ gives:

$$
\begin{equation*}
\lambda=\frac{p(I-A) x}{p B x} \tag{6}
\end{equation*}
$$

It can be proved (Brody (1970) and Johansen (1978)) that we have, in the first approximation:

$$
\begin{equation*}
d \lambda=-p(d A+\lambda d B) x / p B x \tag{7}
\end{equation*}
$$

From (6) and (7) we get

$$
\begin{equation*}
d \lambda / \lambda=\tilde{\rho}=\frac{-p(d A+\lambda d B) x}{p(I-A) x}=-p(d A+\lambda d B) x / y \tag{8}
\end{equation*}
$$

with $\tilde{\rho}$ formally similar to $\rho$ in (2). The definition of production is, however, more comprehensive and the matrix $A$ contains, in addition to the ordinary flow coefficients, also the coefficients of replacement of fixed capital.

### 3.2 The generalized sectoral measure

The sectoral measure suggested here is a generalization of the sectoral measure for wholly integrated sectors suggested by Peterson (1979) and by Wolff (1985). The differences are in the definition of production, i.e. in the fact that here also tangible human capital and active human time are treated as products. Treating active human time as a product means, for instance, that the cost of free services used by persons producing labour of a given type are taken into account in the sectoral measure for a sector utilizing labour of this type.

To show the formal similarity between the sectoral measure suggested here and the earlier measures we will again be following the work of Wolff (ibid.).

In the static input-output model the total requirements of labour and capital per unit of final output are

$$
\begin{gather*}
\beta=l(I-A)^{-1}  \tag{9}\\
\gamma=k(I-A)^{-1} \tag{10}
\end{gather*}
$$

The sectoral rate of total factor productivity growth is then defined as "the inverse of the rate of decrease in total factor requirements per unit of output" (Wolff, ibid.), as follows:

$$
\begin{equation*}
\pi_{j}^{*}=\frac{-\left(w d \beta_{j}+r d \gamma_{j}\right)}{w \beta_{j}+r \gamma_{j}}=\frac{-\left(w d \beta_{j}+r d \gamma_{j}\right)}{p_{j}} \tag{11}
\end{equation*}
$$

This sectoral measure takes into account productivity gains in the production of intermediate inputs. It relates to a composite sector $j$, in which all the sectors contributing directly or undirectly to the final output of sector $j$ are vertically integrated to it. This sectoral measure can also be said to represent the rate of decrease in the equilibrium price of the product of a sector caused by changes in total factor requirements.

Obviously

$$
\begin{equation*}
\rho=\pi^{*} \hat{p} Y / y \tag{12}
\end{equation*}
$$

and the sum of weights in aggregation is equal to unity.
In the dynamic input-output model the total factor requirements, i.e. the contributions to "waiting", per unit of output in different sectors, are:

$$
\begin{equation*}
R=B(I-A)^{-1} \tag{13}
\end{equation*}
$$

The $i j$ 'th elements of matrix $R$ represents the total quantity of the product of sector $i$ that is tied up, directly or undirectly, in the production of a unit of output of sector $j$. It should be remembered that the matrix $B$ does not consist only of the coefficients of fixed capital. It includes also the coefficients of inventory. And there are nonzero stock coefficients even from the sectors producing services and human time, even though they cannot be stored as such. They can, instead, be stored as components of semifinished products (for further discussion, see Aulin-Ahmavaara (1987) and (1990)).

Differentiating (13) gives

$$
\begin{equation*}
d R=B(I-A)^{-1} d A(I-A)^{-1}+d B(I-A)^{-1} \tag{14}
\end{equation*}
$$

The obvious generalization to the total production system of the sectoral measures $\pi_{j}^{*}$ in (11), is

$$
\begin{equation*}
\tilde{\pi}_{j}^{*}=\frac{-p \lambda d R_{j}}{p_{j}} \tag{15}
\end{equation*}
$$

where $d R_{j}$ is the $j$ 'th column of the matrix $d R$. Utilizing the same aggregation as in (12) gives

$$
\begin{equation*}
\tilde{\rho}=\tilde{\pi}^{*} \hat{p} Y / y . \tag{16}
\end{equation*}
$$

The differentiation of the price equation

$$
p=\lambda p B(I-A)^{-1}
$$

gives, in the first approximation:

$$
\begin{equation*}
d p=p \lambda d R+d \lambda p R+\lambda d p R \tag{17}
\end{equation*}
$$

Thus the sectoral measures $\tilde{\pi}_{j}^{*}$ are equal to the price changes caused by the direct effects of technical changes. The secondary effects through the changes in the production costs of the stocks of products being tied up in the production process as well as the through the efficiency of "waiting" $\lambda$ are disregarded.

The unit price of a product, expressed in the unit production costs of simple human time, actually tells how many units of simple human time could have been produced with the resources used to a unit of this product. Then a change in the price of a product can be interpreted as a change in the total factor requirements per unit of this product measured in the factor requirements per a unit simple human time. Accordingly we can give another, more accurate, form to the sectoral measure of technical change in the total production system:

$$
\begin{equation*}
\ddot{\pi}_{j}^{*}=\frac{-d p_{j}}{p_{j}} . \tag{18}
\end{equation*}
$$

Using the same aggregation as in (12) gives

$$
\begin{equation*}
\tilde{*}^{*} \hat{p} Y / y=\frac{-d p_{j}}{p_{j}} \hat{p} Y / y=-d p Y / y . \tag{19}
\end{equation*}
$$

If the total value of final product measured in the unit production costs of simple human time, is kept constant, we have $-d p Y=p d Y$ and accordignly

$$
\begin{equation*}
\dot{\pi}^{*} \hat{p} Y / y=p d Y / y=d \lambda / \lambda, \tag{20}
\end{equation*}
$$

provided that also the total value of capital measured in unit production costs of simple human time is unchanged.

To calculate the values of the sectoral measures in (19), we should be able to express the production prices of the year of comparison in terms of the production price of a unit simple human time in the base year. A method of establishing the link between the prices of two different years would be to utilize the formula (20).

On the other hand, comparisons between the rest of the sectors, with respect to the development of their productivity can be simply performed on the basis of the prices measured in terms of the current year production costs of simple human time. A change in the price of a unit of simple human time only means a uniform relative change in the prices of the rest of the sectors.

The reasons of the changes in the sectoral production costs can be analysed by decomposing these changes for instance into changes in the labour costs, in the costs of intermediate products, in the costs of fixed capital and depreciation. The labour costs would in this case comprise all the costs producing a given type of labour, the costs of human capital and the consumption of free or subsidized services and of time in retirement included.

## 4 Empirical Application to The Finnish Total Production System 1970-1985: The main results

The empirical application represented here includes two versions, which differ in the treatment of the production of simple human capital and of the consumption of persons in retirement. In the basic version it is assumed that one unit of each phase of simple human capital is needed as an input to its next phase. This would mean that, in the balanced growth situation, the size of each generation of children should be $1+\lambda$ times the size of the previous one. This, of course, is not usually the case.

In fact the productivity of labour is normally increasing so that there is no need for the number of children to be equal to the one implied by the balanced growth solution. This is taken into account in the modified version of the application. In the modified version it is assumed that a child belonging to each generation is 1.032 times as productive as a child belonging to the previous one. This means that only $1 / 1.032$ units of each phase of simple human capital is needed as an intput to its next pahse. The number 1.032 has been chosen, because, during the period 1979-88, the growth rate of labour productivity in the business sector in Finland was 3.2 per cent (OECD (1990)). Earlier in the 70's it was somewhat larger, but it is actually the future development of labour producvitity that matters in this case.

It should be noted that for the number of children implied by the modified version to be large enough for the balanced rate of growth given by this version, the productivity of labour should be increasing at the same rate in all its uses, not only in the production of goods and services in the business sector.

In the basic version the ratio of the number of persons in retirement to the number of active persons depends on the rate of growth $\lambda$ and on the length of the productive period and of the period of retirement of human beings (see Aulin-Ahmavaara (1991)). The modified version is based on the actual ratio of number of persons in retirement to the number of active persons, which tends to be larger than the ratio implied by the basic version.

### 4.1 The proximity of the balanced growth output proportions to the actual ones

The distributions of the total output of active human time by type of education are according to the balanced growth output proportions of both of the versions very near to the actual distributions (Table 1). There seems, though, to be a sligth tendency of the actual distribution to have too large a share of persons with only matriculation examination (L4) and too small a share of persons with higher education at the graduate level (L7).

Table 1. Shares of different types of education in the total output of active human time

| Type | 1970 |  |  | 1980 |  |  | 1985 |  |  |
| :--- | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| of ed. | Basic | Mod. | Act. | Basic | Mod. | Act. | Basic | Mod. | Act. |
| L1 | .704 | .704 | .700 | .530 | .533 | .528 | .446 | .451 | .447 |
| L2 | .160 | .160 | .160 | .253 | .251 | .256 | .288 | .286 | .291 |
| L3 | .055 | .055 | .053 | .074 | .073 | .071 | .102 | .101 | .102 |
| L4 | .023 | .024 | .032 | .049 | .050 | .053 | .061 | .063 | .065 |
| L5 | .026 | .026 | .024 | .040 | .039 | .039 | .040 | .039 | .038 |
| L6 | .011 | .011 | .012 | .021 | .020 | .020 | .020 | .020 | .020 |
| L7 | .018 | .018 | .017 | .031 | .031 | .028 | .038 | .037 | .035 |
| L8 | .002 | .002 | .002 | .003 | .003 | .003 | .004 | .004 | .003 |

$\mathrm{L} 1=$ basic, $\mathrm{L} 2=$ secondary, lower level, $\mathrm{L} 3=$ secondary upper level, vocational, $\mathrm{L} 4=$ secondary upper level, nonvocational, $\mathrm{L} 5=$ higher, lowest level. $\mathrm{L} 6=$ undergraduate level, $\mathrm{L} 7=$ graduate level, $\mathrm{L} 8=$ postgraduate level

The proximity of the balanced growth proportions to the actual proportions is, according to both of the versions, very close also in the case of the sectors producing goods and services (Table 2). The main exception is the building sector (G7). A possible explanation to this is the higher growth rate of the sectors producing goods or services. The investment rate of the Finnish economy is also rather high. The sectors producing consumption goods (G3) and services (G12-G13) seem, likewise, to be somewhat overrepresented in the balanced growth solutions, slightly more in the basic version than in the modified one. A possible explanation to this is that the actual number of children (Table 4) is smaller than the one implied by the balanced growth solutions.

Table 2. Shares of different sectors in the total output of goods and services

| Type <br> of ed. | 1970 |  |  | 1980 |  |  | 1985 |  |  |
| :--- | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | Basic | Mod. | Act. | Basic | Mod. | Act. | Basic | Mod. | Act. |
| G1 | .064 | .063 | .059 | .035 | .034 | .036 | .035 | .034 | .034 |
| G2 | .027 | .028 | .029 | .020 | .020 | .020 | .016 | .016 | .016 |
| G3 | .121 | .119 | .109 | .087 | .086 | .082 | .079 | .078 | .075 |
| G4 | .089 | .089 | .091 | .087 | .088 | .089 | .071 | .072 | .075 |
| G5 | .091 | .093 | .097 | .094 | .095 | .098 | .101 | .103 | .100 |
| G6 | .056 | .057 | .057 | .087 | .088 | .084 | .076 | .076 | .079 |
| G7 | .048 | .052 | .063 | .045 | .048 | .061 | .047 | .050 | .059 |
| G8 | .020 | .022 | .025 | .019 | .020 | .018 | .018 | .019 | .018 |
| G9 | .023 | .023 | .022 | .042 | .042 | .041 | .042 | .042 | .041 |
| G10 | .078 | .076 | .073 | .083 | .082 | .082 | .089 | .088 | .086 |
| G11 | .052 | .052 | .050 | .058 | .058 | .057 | .058 | .057 | .054 |
| G12 | .028 | .027 | .027 | .024 | .023 | .022 | .030 | .027 | .025 |
| G13 | .060 | .059 | .055 | .067 | .065 | .061 | .083 | .081 | .077 |
| G14 | .056 | .055 | .050 | .037 | .036 | .034 | .041 | .040 | .037 |
| G15 | .072 | .071 | .066 | .075 | .075 | .072 | .092 | .091 | .094 |
| G16 | .115 | .116 | .127 | .138 | .139 | .144 | .125 | .125 | .130 |

G 1 = agricult. \& fishing, $\mathrm{G} 2=$ forestry, $\mathrm{G} 3=$ manuf. of cons. goods, $\mathrm{G} 4=$ manuf. of wood and paper, $\mathrm{G} 5=$ mining \& metal industries, $\mathrm{G} 6=$ other manuf., $\mathrm{G} 7=$ building, G8 = other contsr., G9 = electr., gas \& water, G10 = trade, financ. inst. \& insurance, G11 = transport \& communic., G12 = education, G13 = other government serv., G14 = ownership of dwellings, G15 $=$ other serv., G16 $=$ foreign trade

Table 3. Deviations of the balanced growth ratio of the total number of active persons to the total output of goods and services from the corresponding actual ratio, per cent

| Year | Basic version | Modif. version |
| :---: | :---: | :---: |
| 1970 | +7.1 | +2.3 |
| 1980 | +5.2 | +0.7 |
| 1985 | +3.6 | +0.4 |

The ratio of the total number of active persons to the total output of goods and services is (Table 3), according the balanced growth solution of the basic version somewhat larger than the actual one. The modified version is very close to the actual situation.

The main imbalance in the actual output proportions is that the actual ratio of the number of children to the number of active persons (Table 4) is remarkably smaller than the one implied by the balanced growth output proportions. In the case of the basic version this is natural because of the increasing productivity of labour. But in the case of the modified version it has been assumed, in the calculation of the coefficients to the production of simple human capital, that there is a 3.2 per cent increase in the productivity of simple human time in all its uses (see pp 13-14). Even in this case the actual ratio remains smaller than the calculated one.

Another imbalance is that the ratio of the total number of adult persons to the number of active persons (Table 5) is in reality larger than according to the balanced growth solution of the basic version.

Table 4. Ratios of the number of children to the number of active persons

| Year | Basic vers. | Modif. vers. | Actual |
| :---: | :---: | :---: | :---: |
| 1970 | .624 | .567 | .418 |
| 1980 | .553 | .491 | .359 |
| 1985 | .497 | .445 | .340 |

Table 5. Ratios of the total number of adult persons to the number of active persons

| Year | Stand. vers. | Actual |
| :---: | :---: | :---: |
| 1970 | 1.148 | 1.239 |
| 1980 | 1.192 | 1.291 |
| 1985 | 1.240 | 1.306 |

### 4.2 The declining overall productivity

The calculated balanced rates of growth indicate a clear fall in the overall productivity of the Finnish total production system during the 70's and an even faster decrease during the first half of the 80 's (Tables 6 and 7 ).

Table 6. Rates of balanced growth, per cent

| Year | Basic version |  | Modified version |  |
| :---: | ---: | ---: | ---: | ---: |
|  | First round | Final round | First round | Final round |
| 1970 | 1.192 | 2.092 | 1.843 | 2.657 |
| 1980 | .884 | 1.668 | 1.408 | 2.123 |
| 1985 | .614 | 1.249 | 1.106 | 1.718 |

Table 7. Changes in the overall productivity, per cent

| Period | Entire period |  | Annual average |  |
| :--- | :---: | :---: | :---: | :---: |
|  | Basic vers. | Mod. vers. | Basic vers. | Mod. vers. |
| $1970-1980$ | -20.28 | -20.08 | -2.24 | -2.22 |
| $1980-1985$ | -25.09 | -19.08 | -5.61 | -4.15 |
| $1970-1985$ | -40.28 | -35.34 | -3.38 | -2.86 |

For the 70 's both of the versions give remarkably similar results. Also the acceleration of the decline in total productivity is obvious according to both of them. The reason why the decline in the 80 's is smaller in the modified version than in the basic version is that the ratio of the total number of adult persons to the number of active persons rises faster in the balanced growth solutions of the basic version than in reality.

The actual growth rates of GDP in the 70's and in the first half of the 80 's, about 3 per cent on the average, were larger than the growth rates displayed
in Table 6. An obvious reason for this is the increasing productivity of labour in the sectors producing goods or services. Therefore the population could grow in the period in question, at a lower rate than the production of goods and services.

As a matter of fact the ratio of the number of children to the number of active persons is, Table 4 , in reality even smaller than the one implied by the modified version in which the increase in productivity of simple human time has been taken into account. This, too, gives more room for a temporarily faster growth, which however cannot be sustained in the long run, unless the labour productivity growth accelerates.

Table 6 shows, besides the calculated final growth rates, also the results of the first round of the outer iteration, which do not include the growth created by growth, i.e. the effects of the rate of growth on the coefficients depending on it.

Table 8. Rates of balanced growth with unchanging per capita consumption of goods and services, per cent

| Base year | Year | Basic version | Modif. version |
| ---: | :---: | :---: | :---: |
| 1970 | 1970 | 2.092 | 2.657 |
|  | 1980 | 2.751 | 3.252 |
|  | 1985 | 2.851 | 3.351 |
| 1980 | 1980 | 1.668 | 2.123 |
|  | 1985 | 1.920 | 2.372 |

In the balanced rates of growth displayed in Table 8 the per capita consumption of goods and services, apart from the educational services used in the production of educated human capital, has been kept on the base year level. It seems that the growth potential of the Finnish economy would have been increasing had the consumption of goods and services not increased. This increase in productivity has however almost literally been eaten up. The problem with this interpretation is that the increased consumption of goods and services has possibly, at least to some extent; been necessary for the improvement of productive capacity of population.

Though the increasing trend of the balanced rate of growth on the assumptions of unchanging per capita consumption is obvious in Table 8, the
results seem partly to depend on the choice of the base year, i.e. on the structure of the consumption of goods and services.

The reasons of the declining growth potential can be analysed by calculating the changes in the production prices i.e. in the ultimate production costs of different sectors of the economy. Here only part of the results will be given. Further results can be found in Aulin-Ahmavaara (1992).

### 4.3 The increasing production costs of educated human capital

The production prices of educated human capital in terms of current year production cost of simple human time have had in general an increasing trend (Table 9). The exceptions are the post graduate education and the nonvocational education at the upper level of secondary education. The latter ran be attributed to the decreasing number of drop-outs and failures to pass one's form. This might, of course, also be a sign of a change in the quality of this type of education.

Table 9. Annual average changes in the ratios of the production prices of different types of human capital to the production price of simple human time, per cent

| Type of education | Basic version |  |  | Modified version |  |  |
| :--- | ---: | ---: | ---: | ---: | ---: | ---: |
|  | $80 / 70$ | $85 / 80$ | $85 / 70$ | $80 / 70$ | $85 / 80$ | $85 / 70$ |
| Basic | -.31 | -.76 | -.46 | -.29 | -.59 | -.39 |
| Sec., lower level | .60 | 1.72 | .97 | .60 | 1.77 | .99 |
| Sec., upper level, voc. | .96 | -.76 | .38 | .99 | -.69 | .43 |
| Sec., upper level, nonvoc. | -1.43 | -1.0 | -1.29 | -1.45 | -.98 | -1.30 |
| Higher, lowest level | -.81 | 1.74 | .03 | -.87 | 1.79 | 0 |
| Undergraduate level | -.16 | 1.35 | .34 | -.21 | 1.39 | .32 |
| Graduate level | .24 | 1.19 | .56 | .19 | 1.24 | .54 |
| Postgraduate level | -.48 | -.35 | -.44 | -.55 | -.30 | -.46 |

It is not (except in the case of simple human time) enough to have a unit of human capital of a given type to produce active human time of this same type. For instance to produce human time at the graduate level at least a unit of simple human capital and a unit of human capital with secondary education at the upper level are needed, in addition to a unit of graduate level human capital. Because a unit of simple human capital is involved in
the production of all types of active human time it is the differences in the production costs of educated human capital involved in the production of different types of active human time that determine the differences in the production costs of different types of human time.

Table 10. Annual average changes in the ratios of the production prices of educated human capital tied up in the production of different types of human time to the production price of simple human time, per cent

| Type of education | Basic version |  |  | Modified version |  |  |
| :--- | ---: | ---: | ---: | ---: | ---: | ---: |
|  | $80 / 70$ | $85 / 80$ | $85 / 70$ | $80 / 70$ | $85 / 80$ | $85 / 70$ |
| Sec., lower | 1.38 | 2.69 | 1.81 | 1.38 | 2.73 | 1.82 |
| Sec., upper, voc. | 1.59 | 2.35 | 1.84 | 1.59 | 2.57 | 1.85 |
| Sec., upper, nonvoc. | -1.43 | -1.00 | -1.29 | -1.45 | -.98 | -1.30 |
| Higher, lowest level | .34 | 2.23 | .97 | .30 | 2.28 | .95 |
| Undergraduate level | -.68 | .46 | -.30 | -.71 | .50 | -.31 |
| Graduate level | -.32 | .52 | -.04 | -.35 | .57 | -.04 |
| Postgraduate level | 0 | -.55 | -.19 | -.05 | -.52 | -.20 |

The rise in the total production costs of educated human capital involved in the production of human time with vocational education has speeded up during the first half of the 80 's (Table 10). The development of the total production costs of educated human capital involved in the production of human time with university education is more favourable in Table 10 than the development of the production costs in Table 9. The reason for this is the decreased production price of human capital with matriculation examination, discussed above.

Taking into account the problems with the data on the flows within the education system, it is possible that the rise in these costs has in the case of vocational education been even larger than shown in Table 10. The development of the production costs, however, is remarkably similar according to both of the versions.

### 4.4 The uneven development of the production prices of goods and services

The units of measurement of the quantities of goods and services are in each of the years equal to a quantity worth 100000 FIM. This of course means
that the units gets smaller along with the rising prices. In Table 11 this has been taken into account by multiplying the production prices by the implicit price indices of the respective sectors in the national accounts, with 1970 as the base year.

Because of the unit of measurement, all the sectors producing goods and services have the same unit price, 100000 FIM. If the actual price proportions were equal to the production prices calculated by the model i.e. to the ultimate production costs, then obviously the production prices of all the sectors producing goods and services should be equal. As can be readily seen from Table 11 this however is by far not the case.
Table 11. Ratios of the production prices of goods and services to the production price of simple human time

| Sector | Basic version |  |  | Modified version |  |  |
| :--- | :---: | :---: | :---: | :---: | :---: | :---: |
|  | 1970 | 1980 | 1985 | 1970 | 1980 | 1985 |
| Agric.\& fishing | 5.330 | 3.534 | 3.142 | 5.423 | 3.603 | 3.209 |
| Forestry | 1.801 | 1.097 | 1.097 | 1.840 | 1.126 | 1.128 |
| Man. of cons. goods | 3.469 | 2.218 | 1.913 | 3.540 | 2.265 | 1.958 |
| Man. of wood \& paper | 1.981 | 1.609 | 1.343 | 2.035 | 1.653 | 1.384 |
| Mining \& metal ind. | 2.148 | 1.397 | 1.044 | 2.201 | 1.429 | 1.071 |
| Other manufact. | 2.045 | 2.292 | 1.887 | 2.098 | 2.351 | 1.938 |
| Building | 2.127 | 1.802 | 1.673 | 2.170 | 1.839 | 1.709 |
| Other construct. | 2.284 | 1.933 | 1.670 | 2.334 | 1.972 | 1.706 |
| Electr. ,gas \& water | 1.961 | 2.225 | 1.608 | 2.061 | 2.312 | 1.675 |
| Trade, fin. inst. \& ins. | 2.434 | 1.826 | 1.596 | 2.487 | 1.865 | 1.633 |
| Transport \& comm. | 2.336 | 1.783 | 1.600 | 2.397 | 1.829 | 1.643 |
| Education | 1.343 | 1.376 | 1.336 | 1.392 | 1.419 | 1.383 |
| Other gov. serv. | 2.551 | 2.047 | 1.785 | 2.640 | 2.108 | 1.838 |
| Ownership of dwell. | 1.582 | 1.178 | 1.044 | 1.718 | 1.286 | 1.144 |
| Other services | 2.203 | 1.944 | 1.765 | 2.257 | 1.991 | 1.811 |
| Foreign trade | 2.432 | 1.791 | 1.744 | 2.493 | 1.836 | 1.790 |

The production price of the agricultural sector is exceptionally high. This is partly due to the relatively large net subsidies received by the agricultural sector. In this study all the market industries are assumed to participate on equal basis to the expenditures of those government services which are not used directly as personal services by population. Accordingly they are
allocated as inputs to the market industries in proportion to the value added generated by these industries.

An even more important reason of the high production prices in agriculture is that the share of labour costs in the unit price is according to our analysis remarkably higher than it is according to the national accounts. However, the latter cannot be exactly calculated because the labour costs of the farmers are not separated from their operating surplus in the national accounts.

The higher ultimate labour costs in agriculture shown by the model are due to the fact that the ratio of the production price of simple human time to the production costs of other types of human time is higher than the corresponding wage ratio. This is to be expected because of progressive taxation and the differences in the receipts of income transfers and in the use of free or subsidized services between persons at different income levels. This means that sectors utilizing human time with higher educational qualifications are actually paying part of the production costs of sectors utilizing human time with lower education. Agriculture is typically a sector of the latter type.

The relatively high production price of manufacturing of consumption goods again can be attributed to the high production price of agriculture. An additional reason are the commodity subsidies paid for the farm products.

An exceptionally low production price can be found in forestry. This is due to the fact that capital stock tied up with the timber growing in the forests has not been taken into account. Partly it belongs to the natural resources and needn't be taken into account in the production costs in the sense of this study. But partly this stock is a result of different measures to improve forests. This part actually belongs to the produced capital stock.

The fact that educational services is a sector utilizing human time with higher education, again, makes it a sector of a relatively low production price. One reason to the relatively low production price of the sector producing dwelling services is that, in the model, it is the real interest rates and not the nominal ones that count. And the real interest rates given by the model of course ar smaller than the actual ones.

The production prices in terms of current year production prices of simple human time have been declining, with a few exceptions, in all the sectors producing goods and services according to both of the versions (Table 12).

Accordingly the sectors producing ordinary goods or services have shown
better productivity development than the sectors producing human capital. The results based on the two versions of the model are very similar.

Tables 13 and 14 serve to explain the changes in the unit prices displayed in Table 12. The results given in Table 13 as well as those in the first two columns of Table 14 are based on the basic version of the model. The corresponding results based on the modified version are not shown here, because they are practically identical with those of the basic version, the largest difference being 0.1 percentage points. The results concerning the unit production costs of replacement of fixed capital are given, in Table 14, according to both of the versions. The differences between the models are in this case somewhat larger, although still very small indeed.

The main reason to the unfavourable productivity development in other manufacturing and in electricity, gas and water services is, Tables 13 and 14, the increasing unit costs of inputs of goods and service. This can in both cases be attributed to the rising oil prices.

Table 12. Annual average changes in the ratios of the production prices of goods and services to the production price of simple human time

| Sector | Basic vesion |  |  | Modified version |  |  |
| :--- | :---: | :---: | :---: | :---: | :---: | :---: |
|  | $80 / 70$ | $85 / 80$ | $85 / 70$ | $80 / 70$ | $85 / 80$ | $85 / 70$ |
| Agriculture \& fishing | -4.03 | -2.32 | -3.46 | -4.01 | -2.28 | -3.44 |
| Forestry | -4.84 | -0.01 | -3.25 | -4.79 | +0.03 | -3.21 |
| Man. of cons. goods | -4.37 | -2.91 | -3.89 | -4.37 | -2.87 | -3.87 |
| Man. of wood \&paper | -2.06 | -3.55 | -2.56 | -2.06 | -3.50 | -2.54 |
| Mining \& metal ind. | -4.21 | -5.65 | -4.69 | -4.22 | -5.61 | -4.69 |
| Other manufacturing | +1.14 | -3.82 | -0.54 | +1.14 | -3.79 | -0.53 |
| Building | -1.64 | -1.48 | -1.59 | -1.64 | -1.45 | -1.58 |
| Other construction | -1.66 | -2.88 | -2.06 | -1.67 | -2.85 | -2.07 |
| Electric.,gas \& water | +1.27 | -6.28 | -1.31 | +1.16 | -6.24 | -1.37 |
| Trade, fin. inst. \& ins. | -2.83 | -2.66 | -2.78 | -2.84 | -2.62 | -2.76 |
| Transport \& commun. | -2.66 | -2.15 | -2.49 | -2.67 | -2.13 | -2.49 |
| Education | +0.24 | -0.58 | -0.04 | +0.18 | -0.51 | -0.04 |
| Other gov. services | -2.18 | -2.70 | -2.35 | -2.23 | -2.70 | -2.39 |
| Ownership of dwell. | -2.90 | -2.39 | -2.73 | -2.85 | -2.31 | -2.67 |
| Other services | -1.24 | -1.92 | -1.47 | -1.25 | -1.88 | -1.46 |
| Foreign trade | -3.01 | -0.54 | -2.19 | -3.01 | -0.50 | -2.18 |

Table 13. Annual average changes in the ratios of the production costs of the intermediate inputs of goods and services and of human time to the sectors producing goods and services to the production price of simple human time, per cent

| Sector | Goods and serv. |  | Human time |  |
| :--- | ---: | ---: | ---: | ---: |
|  | $80 / 70$ | $85 / 80$ | $80 / 70$ | $85 / 80$ |
| Agriculture \& fishing | -5.5 | -2.3 | -3.8 | -2.1 |
| Forestry | -4.4 | -0.6 | -6.0 | +0.4 |
| Man. of cons. goods | -4.5 | -2.6 | -3.6 | -4.4 |
| Man. of wood \& paper | -1.7 | -3.1 | -3.2 | -5.2 |
| Mining \& metal ind. | -4.2 | -5.7 | -4.2 | -5.2 |
| Other manufacturing | +3.0 | -4.2 | -3.7 | -1.9 |
| Building | -1.4 | -2.2 | -1.9 | -0.1 |
| Other construction | -1.8 | -2.7 | -1.3 | -2.7 |
| Electric.,gas \& water | +4.0 | -6.5 | -3.6 | -4.0 |
| Trade, fin. inst. \& ins. | -0.8 | -3.0 | -4.1 | -2.2 |
| Transport \& commun. | -1.1 | -3.5 | -4.3 | 0 |
| Education | +0.4 | -1.5 | +0.4 | +0.4 |
| Other gov. services | -2.9 | -2.2 | -1.5 | -2.5 |
| Ownership of dwell. | -4.6 | -1.2 | .. | .. |
| Other services | -2.0 | -.7 | -0.7 | -3.2 |
| Foreign trade | -3.0 | -.5 | .. | .. |

Up-to-date data on the distribution by industry of the intermediate use of goods and services in different types of government services and nonprofit services are not available. There are, it is true, also some other problems with the data on the education sector especially concerning 1970. However, all the evidence points to the unfavourable development in the productivity educational services.

Considering the way in which the value of the government services is calculated in the national accounts a possible explanation to the increasing production costs of the educational services is, Table 13, that the costs of educating teachers has increased more than their actual remuneration.

Table 14. Annual average changes in the ratios of the production costs of fixed capital and replacement of fixed capital tied up in the production of goods and services to the production price of simple human time, per cent

| Sector | Fixed capital |  | Replac. of fixed capital |  |  |  |
| :--- | ---: | ---: | ---: | ---: | ---: | ---: |
|  |  |  | Basic vers. |  | Mod. vers. |  |
|  | $80 / 70$ | $85 / 80$ | $80 / 70$ | $85 / 80$ | $80 / 70$ | $85 / 80$ |
| Agriculture \& fishing | +0.1 | -2.4 | +2.7 | -1.8 | +2.9 | -1.8 |
| Forestry | +0.5 | +2.2 | +0.7 | +1.4 | +0.8 | +1.3 |
| Man. of cons.. goods | -2.6 | -2.9 | -2.3 | -2.6 | -2.2 | -2.6 |
| Man. of wood \&paper | -1.5 | -2.8 | -1.0 | -2.6 | -0.8 | -2.6 |
| Mining \& metal ind. | -3.2 | -5.6 | -2.7 | -5.7 | -2.6 | -5.7 |
| Other manufacturing | -2.3 | -2.1 | -2.0 | -1.6 | -1.9 | -1.6 |
| Building | -0.2 | -0.3 | -1.5 | -2.1 | -1.5 | -2.1 |
| Other construction | -0.5 | -4.6 | -1.2 | -5.2 | -1.2 | -5.2 |
| Electric.,gas \& water | -3.9 | -5.5 | -3.1 | -4.6 | -2.9 | -4.6 |
| Trade, fin. inst. \& ins. | -3.3 | -2.4 | -2.3 | -1.7 | -2.2 | -1.7 |
| Transport \& commun. | -2.5 | -1.9 | -2.4 | -1.6 | -2.3 | 1.6 |
| Education | +0.2 | -0.6 | +1.1 | +0.9 | +1.3 | +0.9 |
| Other gov. services | -2.9 | -3.3 | -1.9 | -1.3 | -1.6 | -1.3 |
| Ownership of dwell. | +0.7 | -1.2 | +2.0 | +1.3 | +2.4 | +1.3 |
| Other services | +0.6 | -1.5 | +2.1 | +0.9 | +2.4 | +1.0 |
| Foreign trade | .. | .. | .. | .. | .. | .. |

Another explanation is, Table 14, that the interest on capital, which in the case of government services is not taken into account in the national accounts, has in the educational services increased more than in the rest of the government services. Besides, in the calculations based on the model of this study the investment in the school buildings also has an immediate effect on the replacement requirements. In national accounts the effects on capital consumption allowances of the increased investement in school buildings will be seen only later.

The relatively unfavourable development of productivity in manufacturing of wood and paper in the 70 's can be partly attributed to the oil price shock. But also costs of the services of fixed capital, Table 14, seem to have developed less well than in the other manufacturing sectors.

The relatively favourable development in the metal industries as compared with for instance the forest industries is explained by the more favourable
development of the production costs of both intermediate inputs, Table 13, and of fixed capital and replacement, Table 14.

The relatively large decrease in the production price in agriculture in the 70 's seems to be due to the deacrease in the production cost of intermediate inputs. This again is mainly caused by the fact that the input from this sector to itself has, according to the input-output tables, fallen sharply from the level of 1970. This might be caused by some change in the compilation of the statistics.

The analysis of the production costs has here been based on the production costs expressed in current year unit production costs of simple human time. Taking into account also the increase in the production price of simple human time would only cause the same relative increase in the production prices. Therefore it was possible to make comparisons between developments in different sectors even though the final levels of the changes in production prices, i.e. in sectoral productivities, are not known.

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# Spillover Effects, Linkage Structure, and Research and Development 

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#### Abstract

We use U.S. input-output data for the 1947-77 period to analyze the relations among R\&D, technical change, and intersectoral linkages. Our most novel finding is that among manufacturing industries, an industry's rate of technological progress is positively and significantly related to that of its supplying sectors. Another new finding is that among all sectors of the economy, a sector's R\&D intensity and rate of technological progress positively affect its degree of linkage with other sectors. We also find significant spillovers from R\&D embodied in new investment.


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# Spillover Effects, Linkage Structure and Research and Development Edward N. Wolff and M. Ishaq Nadiri 

## 1. Introdnction

We investigate three issues in this paper. The first is the "spillover effect" of research and development (R\&D) performed in one industry on technical change in its customers (industries which buy its inputs). The second is whether technical progress in one industry directly affects the rate of technological progress in customers, independently of its level of R\&D activity. The third is whether R\&D or technical progress in an industry affects its linkage structure with other industries in the economy.

R\&D spillovers usually refer to the direct knowledge gains of customers from the R\&D of the supplying industry (see Griliches, 1979). ${ }^{1}$ There have been several approaches to measuring R\&D spillovers. Terleckyj (1974, 1977, and 1980) provides measures of the amount of R\&D "embodied" in customer inputs. Scherer (1981 and 1982), relying on Federal Trade Commission line of business data, uses product $R \& D$, aimed at improving output quality, as a measure of R\&D spillovers.

A third approach is to measure the "technological closeness" between industries. For example, if two industries use similar processes (even though their products are very different or they are not directly connected by interindustry flows), one industry may benefit from new discoveries by the other industry. Such an approach is found in Jaffe (1986) who uses patent data to measure technological closeness between industries. In our own work, we shall distinguish between two possible formulations of R\&D spillover and provide corresponding econometric tests. ${ }^{2}$

The second issue is quite unexplored: As far as we are aware, there have been no previous econometric studies estimating direct technological
spillovers. However, the previous literature is quite suggestive. For the German economy, Oppenlander and Schulz (1981) calculate that only about a third of new products are derived from new technology (i.e., process innovation). The remainder are "market innovations", which are used to open up new markets for the products. Pavitt (1984) estimates that out of 2,000 innovations introduced in the United Kingdom, only about 40 percent were developed in the sector using the innovation. The remaining innovations were borrowed from new technologies developed in other sectors.

The work of Nelson and Winters (1982) illustrates another approach. In their "evolutionary model," spillovers in technology among firms may occur as firms search or sample from their enviromment to develop new production techniques. Moreover, Rosenberg (1982) and Rosenberg and Frischtak (1984) suggest the existence of clusters of innovations in industries that occupy a strategic position in the economy in terms of both forward and backward linkages. They speculate that there are certain intraindustry flows of new equipment and materials that have generated a vastly disproportionate level of technological change and productivity growth in the economy. ${ }^{3}$

The third issue also opens up a relatively new area of research. The linkage issue has a long history in development economics. ${ }^{4}$ The measurement of linkages has also received considerable treatment in the input-output literature.' These indices essentially serve to asses the relative importance of one industry's output as inputs in other industries (the so-called "forward linkage ${ }^{n}$ ). ${ }^{6}$

In our work, linkage structure is important in two ways. First, it provides another index of both R\&D and technological spillovers. Gains from R\&D and technological progress (which we will measure by the rate of total
factor productivity growth) may take the form of an expansion in industry sales from the penetration of new markets (sectors). Indeed, R\&D conducted by an industry may engender a whole new set of customers, if radically new technologies are developed, as the histories of the automobile and computer industries suggest. The expansion of linkages from technological progress may be a consequence of lowered product price or improved product quality. Though we can not distinguish between these two possible effects with our data, we can measure their joint effect on linkage structure. ${ }^{7}$

Second, increasing linkages may be socially beneficial in its own right, since it is tantamount to increasing specialization and division of labor in the economy and hence higher overall productivity. Indeed, Leontief (1966) found that more developed economies had greater linkages among producing sectors (fuller interindustry tables) than less developed ones. This factor was also the basis of the Hirschman (1958) proposal for promoting interindustry linkages as a development strategy.

We use an input-output framework to analyze the relations among $R \& D$, technical change, and intersectoral linkages. Admittedly, though these three relations are necessarily dynamic and may occur with considerable lags, data limitations force us to analyze them contemporaneously. Despite this, we obtain several new and potentially important results. First, we find significant spillovers from R\&D embodied in capital stock. Second, we find that a sector's own rate of total factor productivity growth is significantly related to the total factor productivity growth of a sector's supplying industries. Third, a sector's degree of forward linkage with other sectors is found to be positively related to the sector's R\&D intensity and its rate of total factor productivity growth. Fourth, splitting R\&D data into a
privately-financed and government-financed component, we find stronger effects from private $R \& D$ embodied in inputs than from total embodied R\&D.

The remainder of the paper is organized into four parts. Section 2 presents our basic model and the results on the spillover effects of R\&D. Section 3 provides the results on spillover effects of sectoral technical change. Section 4 considers the relation between $R \& D$, technical change, and linkage structure. Concluding remarks are presented in the last section.

## 2. Spillozer Rffect: of RED

Our model is based on an input-output accounting framework. Let
$X_{t}=$ (column) vector of gross output by sector at time $t$.
$Y_{t}-$ (column) vector of final demand by sector at time $t$.
$A_{t}-s q u a r e$ matrix of inter-industry technical coefficients, $a_{1 j}$, at time $t$.
$L_{t}=$ (row) vector of labor coefficients at time $t, \ell_{1 t}$, showing employment per unit of output.
$K_{t}=$ square matrix of capital stock coefficients, $k_{1 j}$, at time $t$, showing the capital of each type required per unit of output.
$P_{t}=$ (row) vector of prices at time $t$, showing the price per unit of output of each industry.

Unless otherwise indicated, all variables are in real terms. In addition, let us define the following scalars:
$w_{t}=$ the annual wage rate.
$i_{t}=$ the rate of profit on the capital stock at tine $t$.
We can now define a row vector $\pi$, where the rate of TFP growth Eor sector $j$
is given by

$$
\begin{equation*}
\mathrm{TFPGRT}_{j}=\pi_{j}=-\left(\Sigma_{i} \mathrm{p}_{1} \mathrm{da} a_{i j}+w d \ell_{j}+i d k_{j}\right) / p_{j} \tag{1}
\end{equation*}
$$

where $d$ refers to the differential. ${ }^{8}$ This measure is a continuous version of a measure of sectoral technical change proposed by Leontief (1953). Alternatively, since, for any variable $z, d z=z \cdot d \log z$, where $\log$ is the natural logarithm, then sectoral TFP growth is given by
(2) $\quad \pi_{j}=-\Sigma_{i} \alpha_{i j}\left(d \log a_{i j}\right)-v_{L j}\left(d \log \ell_{j}\right)-V_{k_{j}}\left(d \log k_{j}\right)$
where $\alpha_{i j}=p_{i} a_{i j} / p_{j}, \quad v_{i j}=w \ell_{j} / p_{j} ;$ and $v_{k j}=i k_{j} / p_{j}$. These three terms give the current value shares of the respective inputs in the total value of output. Since productivity growth rates are measured over discrete time periods rather than instantaneously, we use the average value share of $\alpha_{i j}$, $V_{L j}$, and $V_{k j}$ over the sample period to measure $\pi$. R\&D is introduced into the model as follows. Let

$$
R D_{j t}=\text { sectors } j^{\prime} s \text { expenditure on } R \& D \text { (in constant dollars) in year } t .
$$

Then, the R\&D intensity of output, $r$, is given by

$$
\operatorname{RDGDO}_{j t}=r_{j t}=R D_{j t} / x_{j t}
$$

which shows the amount of R\&D expenditure (in constant dollars) per unit of output. It should be noted that this differs from the usual treatment, where $R \& D$ intensity is defined as $R D_{j t}$ relative to $G D P$ or value added rather than to gross output $X$. We use this particular form of $R \& D$ intensity in order to be consistent with the other coefficients in an input-output framework and in order to construct measures of $R \& D$ embodied in material inputs. The correlation between RDGDO and the standard measure of R\&D intensity, the ratio
of R\&D to GDP, is quite high, at 0.86 , so that our resules should not differ too much from previous ones on this account.

Following Mansfield (1980), Griliches (1980), and others, we shall begin with the standard form for estimating the return to R\&D:

$$
\begin{equation*}
\operatorname{TFPGRT}_{\mathrm{jt}}-a_{0}+b_{0} R^{2} D \mathrm{DO}_{\mathrm{jt}}+\Sigma c_{t} D_{t}+\epsilon_{\mathrm{jt}} \tag{3}
\end{equation*}
$$

where $a_{0}$ is a constant, $b_{0}$ the rate of return of $R \delta D, D_{t}$ are time dummies and $c_{t}$ the corresponding coefficients, and $\epsilon_{j t}$ is a stochastic error term. Equation (3) is derived from the assumption that the (average) rate of return to R\&D is equalized across sectors. Time dumies are introduced to allow for period-specific effects on productivity growth not attributable to R\&D.

A word should be said about the stochastic properties of the model. We implicitly assume a one-factor, fixed effect model in the corresponding level equation, of the form:

$$
\log x_{j t}-v_{M j} \log \mu_{j t}-v_{L j} \log \Lambda_{j t}-v_{k j} \log \kappa_{j t}=\gamma_{t}+\beta \log \operatorname{RDSTK}_{j t}+\eta_{j}+\epsilon_{j t}
$$ where $\Lambda$ is total employment; $\kappa$ is total capital stock; for expositional convenience, $\mu$ is total intermediate inputs and $v_{M}$ the corresponding value share; RDSTK $_{j t}$ is the stock of $R \& D$ capital of sector $j$ at time $t_{\text {; }}$ and $\eta_{j}$ controls for time invariant unobservable industry heterogeneity. It is assumed that the $\epsilon_{j t}$ are independently distributed.

We can derive equation (3) by first-differencing the above equation to yield:

$$
\operatorname{TFPGRT}_{\mathrm{jt}}=a_{0}+\beta \mathrm{d}\left(\log \operatorname{RDSTK}_{\mathrm{jt}}\right)+\Sigma c_{t} D_{t}+\epsilon_{\mathrm{jt}}
$$

To obtain (3), note that $\beta=\left(\partial x_{j t} / x_{j t}\right) /\left(\partial \operatorname{RDSTK}_{j t} / \operatorname{RDSTK}_{j:}\right)$, sc =iez

$$
\begin{aligned}
\beta \mathrm{d}\left(\log \operatorname{RDSTK}_{j t}\right) & =\left(\partial \mathrm{x}_{\mathrm{jt}} / \partial \operatorname{RDSTK}_{\mathrm{jt}}\right) \cdot\left(\operatorname{dRDSTK}_{\mathrm{jt}} / \mathrm{dt}\right) / \mathrm{x}_{\mathrm{jt}} \\
& =\mathrm{b}_{0}\left(\mathrm{RD}_{\mathrm{jt}} / \mathrm{x}_{\mathrm{jt}}\right)
\end{aligned}
$$

where $b_{0}=\partial x_{j t} / \partial \operatorname{RDSTK}_{j t}$ is the rate of return to R\&D under the assumption that it is constant across industries and over time; and $R D_{j t}=\operatorname{dRDSTK}_{\mathrm{jt}} / \mathrm{dt}$ is the annual expenditure on $R \& D$.

The advantage of this formulation is that no assumption is required regarding the stochastic properties of $\eta_{t}$ (for example, whether it is independent of the exogenous variables or of $\epsilon$, or whether it is independently or identically distributed). By assumption, the $\epsilon_{\mathrm{ft}}$ are independently distributed, but may not be distributed identically. For the regressions reported in Tables 3,4 , and 5 below, we also re-estimated them using the White procedure for a heteroschedasticity-consistent covariance matrix, with very similar results (results not shown).

We introduce forward spillovers from R\&D on the basis of trade flows between sectors. However, we distinguish between two different formulations of R\&D spillovers. The first assumes that the amount of information gained from supplier i's R\&D is proportional to its importance in sector j's input structure (that is, the magnitude of $a_{i j}$ ) and its $R \& D$ expenditure relative to the output of sector $j$ (that is, the ratio of $R D_{i}$ to $x_{j}$ ). Then the amount of indirect R\&D (RDMIND) received by sector $j$ (from material inputs) is given by:

$$
\operatorname{RDMIND}_{j}=\Sigma_{i} R D_{i} a^{0}{ }_{i j} / x_{j}
$$

where $A^{\circ}$ is identical to the $A$ matrix except that the diagonal is set to zero to prevent double-counting of R\&D expenditures. The second assumes that the amount of $R \& D$ that spills over from sector $i$ to sector $j$ is proportional to
the amount of output sector $i$ sells to $j$. This approaci. :s used by Terleckyj (1974, 1977, and 1980). Define the sales coefficient $b_{i j}$ as:

$$
b_{1 j}=a_{1 j} x_{j} / x_{1}
$$

which shows the percentage of sector i's output that is sold to sector $j$. Then, the alternative measure of indirect R\&D (RDMINDA) is given by ${ }^{9}$

$$
\operatorname{RDMINDA}_{j}=\left(\Sigma_{1} b_{i j} R D_{i}\right) / x_{j}
$$

A similar approach is used by Scherer (1981 and 1982), except that his measure of indirect R\&D is based on the number of patents issued by sector 1 which falls in sector $j$ 's industrial classification. In principle, his measure is identical to RDMINDA, except that indirect R\&D is distributed proportional to patents instead of sales.

The two approaches can be contrasted as follows. In the first, R\&D performed by industry i is treated as an industry-wide public good whose (indirect) benefit is the same for each sector which buys from industry i. The benefit industry $j$ receives is proportional to input i's importance in j's production structure (the coefficient $a_{i j}$ ). In the second, R\&D is implicitly treated as a sector-specific product. Thus, a sector that engages in R\&D and sells $p$ percent of its output to sector $j$ will, in a sense, indirectly devote p percent of its R\&D to improving sector j's technology (either through product improvement or new knowledge). As with its own R\&D, the productivity effect is proportional to borrowed R\&D as a percent of $j$ 's output, $x_{j}$.

Another source of borrowed $R \& D$ is new investment. As far as we are aware, this source has not received attention in the spillover lizerature. In this case, we assume that the information gain is proportional to the annual investment flow (the time derivative of the capital stock) pe: $\because=:=0$ output:

$$
\operatorname{RDKIND}_{j}=\Sigma_{i} R D_{1} k_{i j} / x_{j}
$$

where a dot (.) indicates the time derivative. ${ }^{10}$
The new addition to sector j's stock of knowledge is the sum of its own R\&D and that borrowed from other sectors. The estimating model is then given by
(4) TFPGRT $_{j t}=a_{0}+b_{0}$ RDGDO $_{j t}+b_{2}$ RDMIND $_{j t}+b_{2}$ RDKIND $_{j t}+\Sigma c_{t} D_{t}+\epsilon_{j t}$ where $D_{t}$ represent dumny variables for time periods. This specification is similar to that of Terleckyj (1974, 1977, and 1980), except that no estimate of R\&D embodied in capital stock was included in his work. ${ }^{11}$ Here, it should be stressed that we have not considered the ability of or the costs to the borrowing sector to absorb technical change.

Results on R\&D Spillovers. Our basic data source consists of U.S. inputoutput tables, which are available on an 87 -sector level from official sources for years 1947, 1958, 1963, 1967, and 1972, and 1977. All matrices were deflated to 1958 dollars using sectoral price deflators. In addition, data on employment and capital stock by sector were obtained for each of the six years. ${ }^{12}$ Because of 1 imitation of R $\delta D$ stock data, it was necessary to aggregate the 51 manufacturing sectors in the input-output tables to 19 sectors (see Table 1). Capital utilization rates were obtained on the 21order level. ${ }^{13}$ Finally, estimates of average yearly RoD expenditure in constant dollars for each of the 19 aggregated manufacturing sectors in each of the five time periods were obtained from published National Science Foundation data. Most of the series ran from 1951 to 1978 , and R\&D data from 1951 to 1958 were used to estimate average R\&D expenditure for the 1947-58 period. ${ }^{14}$

We begin with some descriptive statistics (see Table 2). Annual rates of TFP growth in manufacturing over the $1947-77$ period range from a high of 1.9 percent in chemicals to a low of -0.2 percent in lumber and wood products. The unweighted average across all manufacturing industries is 0.65 percent per year. Average $R \& D$ intensity ( $R \& D$ as a percent of $G D O$ ) among all industries over the 1947-77 period is 1.8 percent, ranging from a high of 9.6 percent in transport equipment to a low of 0.05 percent in textiles and apparel. The simple correlation coefficient between TFP growth (TFPGRT) and R\&D intensity (RDGDO) is a positive 0.39. Moreover, dividing the 19 manufacturing industries into groups of five (four for the bottom group) according to their rate of TFP growth, we find that the group with the highest TFP growth also had the highest average R\&D intensity (3.2 percent), followed, in turn, by the next group, the second lowest group, and the bottom group (bottom panel of Table 2).

R\&D embodied in intermediate inputs (RDMIND) ranges from a high of 0.027 in transport equipment to a low of 0.001 in tobacco products. RDMIND is also positively correlated with TFP growth, 0.34 . The average value of RDMIND is highest for the top five industries ranked by TFP growth, followed, sequentially, by the next five, the next lower group, and the lowest group. In contrast, R\&D embodied in capital investment (RDKIND) shows almost no correlation with TFP growth among manufacturing industries, and its average group value does not have the same rank order as TFP growth among the four groups.

Regressions were pooled over five time periods: 1947-58, 1958-63, 196367, 1967-72, and 1972-77. The use of synchronic time periods .- in this case, five -- is new in the literature, which typically presents estimates of the
return to R\&D based on single-period regressions. These estimates may be period-dependent. Our approach allows us to capture long-term effects of R\&D on productivity. Moreover, since R\&D data were available only for manufacturing sectors, most regressions were performed only on manufacturing sectors. Other specifications, when appropriate, were performed across all sectors (50 in all).

Regression results on R\&D spillovers are shown in Table 3. R\&D intensity is significantly related to sectoral TFP growth at the 5 percent significance level. The estimated direct return to $R \& D$ was about 11 percent among exclusively manufacturing sectors but 20 percent among all sectors. These estimates fall in the low part of the range of previous estimates of the direct rate of return to $R \delta D$, which range from about 3 percent (Griliches and Lichtenberg, 1984a) to 76 percent (Griliches and Lichtenberg, 1984b). (Also see Table 1 of Nadiri, 1991, and the paper for an extensive review of the literature). Our estimates are likely on the low side because we use TFP growth based on gross output (including intermediate inputs), instead of value added (excluding intermediate inputs), so that our estimates of sectoral TFP growth are about half those based on value added. ${ }^{15}$

The estimated indirect return to R\&D based on RDMIND is found to be 14 percent among manufacturing sectors and 8 percent among all sectors. These estimates also fall within the range of previous estimates, which vary from 11 percent (Bernstein and Nadiri, 1988) to 183 percent (Terleckyj, 1980), though are, again, on the low side (also see Table 2 of Nadiri, 1991). Moreover, the coefficient estimates are not statistically significant. This has been the case in several other studies (see, for example, Odagiri, 1985). ${ }^{16}$

We also find that R\&D embodied in capital stock (RDKIND) is significant at the 10 percent level among all sectors, with an estimated rate of return of 9 percent. ${ }^{17}$ This, as far as we are aware, is a new finding. Moreover, by adding together RDGDO, RDMIND and RDKIND, we obtain estimates of the total or social rate of return to $R \& D$ of 27 percent within manufacturing and 42 percent among all sectors, both significant at the one percent level. These again fall within the range of previous estimates

The time dumy variables fall into a consistent pattern (results not shown). They indicate that the general rate of TFP growth, not attributable to R\&D, was highest in the $1958-63$ period, followed by the $1963-67$ period, the 1947-58 period, the 1967-72 period, and, lastly, the $1972-77$ period. These results correspond directly to the general pattern of productivity growth over the postwar period, particularly the post-1967 productivity slowdown. The Fstatistics for the time dumy variables as a group are significant at the one percent level.

We also include direct measures of forward industry linkage (see section 3 below) as explanatory variables in equation (4). The argument here is that the existence of a large array of customer industries may stimulate the development of new technology in the supplying industry because of knowledge flows fron customer to supplier. However, the forward linkage variables are found to be statistically significant. But, as we shall see below, the converse is not the case. ${ }^{18}$

Soillover Effects of Private and Government-Financed R\&D. Using National Science Foundation data, we split R\&D expenditures in each period into one part that was financed by private sources ("private" R\&D) and a second part that was government-financed. Company-financed R\&D comprised more than 90
percent of total $R \& D$ spending in all industries except rubber products (SIC 30); engines, machinery and industrial equipment (SIC 35); electrical machinery and appliances (SIC 36); motor vehicles and transportation equipment (SIC 37); and scientific equipment and supplies (SIC 38). Indeed, in electrical machinery and transportation equipment, government-financed R\&D accounted for about two-thirds of total R\&D.

We first estimate the return to privately-financed R\&D, RP, and government-financed R\&D., RG, by dividing RDGDO into these two components:

```
RDGDO - RDPGDO + RDGGDO
```

As found in other studies ${ }^{28}$, the return to private $R \& D$ is much higher and more significant than that to total R\&D. In manufacturing, the estimated rate of return is about 40 percent and among all sectors about 60 percent (see Table 4). The return to government-financed R\&D is statistically insignificant. It is possible that the effect of government-financed $R \& D$ is indirect via an inducement to increase company-financed R\&D. However, recent results by Lichtenberg (1984) suggest the opposite. Also government R\&D is concentrated in a few industries and probably is undertaken for objectives other than promotion of overall productivity growth. Moreover, as Griliches (1986) has suggested, most of the direct output of federally funded research is "sold" back to the government at a "cost-plus" basis and is thus not likely to be reflected in the firm's productivity.

It is also possible to develop measures of borrowed privately-financed and government-financed $R \& D$, and assess their effect on productivity growth. Results for private R\&D embodied in intermediate inputs (RDPMIND) is statistically significant, at the 10 percent level, among manufacturing
industries. The estimated indirect rate of return is 17 percent. However, RDPMIND is insignificant across all sectors of the economy (results not shown). Private R\&D embodied in new investment (RDPKIND) is statistically significant at the five percent level among all sectors of the economy, with an estimated indirect rate of return of 11 percent. However, the variable is insignificant among manufacturing sectors (results not shown). Borrowed government-financed $R \& D$ is uniformly insignificant (results not shown).

## 3. Spililoxer Bffects of Technical Change

We next construct estimates of direct technological spillovers in analogous fashion to that of R\&D spillovers. Thus

$$
\text { TFPIND }_{j}-\Sigma_{1} \pi_{1} a^{0}{ }_{1 j}
$$

is a measure of sector $j$ 's indirect knowledge gain from technological progress in its supplying sectors. According to the descriptive statistics, shown in Table 2, the average value of TFPIND over the five periods 1947-58, 1958-63, 1963-67, 1967-72, and 1972-77, ranges from a low of -0.003 in petroleum refining to a high of 0.008 in textiles and apparel. TFPIND is strongly correlated with industry TFP growth, with a correlation coefficient of 0.60 . The average value of TFPIND is over three times as great in the group of industries with the highest (direct) TFP growth than in the group with the lowest TFP growth, and about twice as great as in the middle two groups of industries.

Results are shown in Table 3. The principal finding is that among manufacturing sectors, an industry's TFP growth is positively and significantly related to the TFP growth of its supplying sectors. Since

TFPIND $_{j}=\left[\begin{array}{ll}\Sigma_{1} & a^{0}{ }_{1 j} \pi_{i} / \Sigma_{1} a^{0}{ }_{1 j}\end{array}\right] \cdot\left[\begin{array}{ll}\Sigma_{1} & a^{0}{ }_{1 j} / 1\end{array}\right]$,

TFPIND can be interpreted as a weighted average of the TFP growth of supplying sectors multiplied by the ratio of the value of intermediate inputs to the total value of inputs. Since the latter ratio averages about 0.6 , this indicates that a one percentage increase in the TFP growth of a sector's suppliers would be associated with a half percentage point "productivity pass through" in the sector"s own productivity growth.

As with other specifications for the manufacturing sample, the R\&D intensity variable is significant at the 5 percent level, and its estimated coefficient is 0.11 . By the usual criteria ( $R^{2}$, adjusted $R^{2}$, and standard error of the regression), this form provides the best fit of the four shown in Table 3 for the manufacturing sample. However, indirect TFP proved to be insignificant in regressions run across all sectors. The likely reason is that while within manufacturing there is sufficient technological closeness to promote direct borrowing among industries, this is not the case among the major sectors of the economy (between manufacturing and various services, for example).

## 4. Link Re Structwre

To measure linkages, we use three indices developed in the input-output literature. The first is the average value of the value coefficients, $a^{*}{ }_{1 j}$, (defined as $p_{i} a_{i j} / p_{j}$ ):

$$
\operatorname{LINKI}_{1}-\sum_{j \neq i} a_{i j}^{*} /(N-1)
$$

where $N$ is the number of sectors ( 50 in our case). ${ }^{20}$ The second index is the row sum of the value inverse matrix:

$$
\operatorname{LINK}_{i}=\Sigma_{j}\left[\left(I-A^{*}\right)^{-1}\right]_{i j}
$$

This measure shows the total increase in output in sector $i$ that would be forthcoming to meet a dollar increase in the demand for the output of each sector of the economy. This index expresses the extent to which the system of industries in the economy draws upon industry i in order to expand production. The third is given by

$$
\text { LINK3 }_{j}=\Sigma_{i}\left[\left(I-B^{\prime}\right)^{-1}\right]_{i j}
$$

The column sum of the ( $I$ - $B^{\prime}$ ) inverse matrix shows the total output of user industries needed to absorb an additional dollar of sector i's output.

Descriptive statistics for LINK2, shown in Table 2 , indicate a range of values from 1.08 , in the furniture sector (primarily sells household consumption goods), to 4.76, in primary metals (sells almost exclusively to other industries). Among manufacturing industries, there is almost no correlation between LINK2 and industry TFP growth (the correlation coefficient is 0.07 ). Moreover, groupings by industries ranked by TFP growth indicate that the average value of LINK2 is highest for the bottom group, second highest for the top group, third highest for the next to bottom group, and lowest for the second group.

Regression results are shown in Table 5. The various linkage indices are regressed alternately on sectoral TFP growth and RoD intensity. ${ }^{21}$ Among all sectors, R\&D intensity and TFP growth are generally positive and statistically significant. This result must be interpreted with some caution, since it may simply reflect the greater forward linkage of manufacturing (high R\&D and relatively high productivity growth sectors) with non-manufacturing sectors
due to the position of manufacturing in the normal production flow between primary and final output. On the other hand, among exclusively manufacturing industries, no statistically significant relations are found. However, it is possible that this negative finding is due to the high level of aggregation within the manufacturing sector (to 19 industries), and that further disaggregation might produce significant results.

Finally, we can assess the effect of both private and government-financed R\&D on linkage structure. As shown in Table 4, we find very significant positive effects of private R\&D intensity on the degree of forward linkages among all sectors. Both the estimated coefficients and the significance levels are greater than for corresponding forms using total R\&D intensity. Government-financed R\&D, on the other hand, is uniformly insignificant as a determinant of linkage strength.

## 5. Conclusions

As in most previous studies, we find a statistically significant relation between the R\&D intensity of a sector and its rate of productivity growth. We also find, as in other studies, spillover effects of R\&D embodied in intermediate inputs within manufacturing. The results are statistically significant for private R\&D embodied in intermediate inputs, but not for total embodied R\&D. However, a new finding here is that R $\& D$ embodied in capital stock, and even more strongly private $R \& D$ embodied in capital stock, is found to have statistically significant spillover effects on sectoral TFP growth among all sectors. However, within manufacturing, spillover effects of R\&D embodied in capital stock are not significant.

Our most novel finding is that within manufacturing the TFP growth of supplying sectors is significantly related to a sector's own productivity
growth. However, among all sectors this relation is not statistically significant. The likely reason is that among manufacturing firms, the technologies of different industries are sufficiently close to permit direct borrowings of new processes, whereas anong all sectors, technologies of the various industries differ too much. Thus, it appears that within manufacturing, new technical knowledge is borrowed by observing the new technology of suppliers, whereas among non-manufacturing industries the borrowing of knowledge takes place through the acquisition of new capital stock.

Another new finding is that the degree of forward linkage of a sector is positively and significantly related to both its R\&D intensity (particularly, company-financed R\&D) and its rate of TFP growth. The results lend support to our argument that $R \delta D$ and technological progress, through quality improvement, lowered price, and the development of new products, expands an industry's market and leads to a greater number of new customers.

Our results are admittedly crude and only suggestive because of the high level of aggregation of the data, particularly in manufacturing. However, they do point the way toward the importance of technological spillovers among closely connected industries. Such "agglomeration" effects have been discussed by others (see, for example, Rosenberg, 1982), but this is apparently the first direct evidence of technological change in one sector affecting TFP growth in purchasing sectors and affecting the degree of forward linkage. Hopefully, greater disaggregation will lend greater support to our conclusions. It would also be interesting to consider in greater detail the role of different inputs as carriers of new technology, particularly different components of capital investment.

Moreover, though, unfortunately, our analysis ends in 1977 (limited by available input-output data), we suspect that the results on inter-sectoral spillovers may be heightened during the l980s because of the paradigmatic shift from electromechanical automation to information technologies (see, David, 1991, for example). Indeed, this study has not been able to adequately capture the role of computerization in the spread of new technologies, a process that was likely to have been particularly important during the 1980 s.

Another potential area of future research is the role of imported technology. This issue can be addressed in similar fashion by, for example, breaking out imported intermediate inputs and capital goods from domestically produced ones, where the data pernit. Such an analysis could consider the effects of R\&D embodied in such inputs, as well as the effects of technological progress in the (foreign) industries producing these goods. Correspondingly, one could consider the role of $R \delta D$ embodied in exports and the technological progress of industries producing exports on productivity growth in export destination countries.

## FOOTNOTES

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${ }^{1}$ Griliches also identifies a second, less comon interpretation of spillovers -- namely, that inputs purchased from an industry engaging in R\&D may embody quality improvements that are not fully appropriated by the supplier. It should be emphasized at the outset that while these two notions of spillovers are quite distinct, we can not distinguish either analytically or statistically between them in our work.

2 For other treatments of R\&D spillovers, see National Science Foundation (1977), Nadiri (1979), Griliches (1980a, 1980b), Mansfield (1980), and Griliches and Lichtenberg (1981). Also, see Mohnen (1990) and Nadiri (1991) for recent reviews.

3 The aircraft industry is an example of a sector has often worked closely with its major customer, the airlines, to develop new products. Pan American Airways, for example, had an historically close relationship with Boeing in the design of new aircraft. See Newhouse (1982) for details.

4 See, for example, Hirschman (1958) or Leontief (1966) for early treatments of these issues.

5 See, for example, Chenery and Watanabe (1958), Jones (1976), or Bulmer-

Thomas (1982).

6 "Backward linkage" refers to the importance of one sector as a market for the outputs of other sectors. Though this has also received attention in the input-output literature, we will not emphasize it here.

This argument is related to what is commonly referred to as Verdoorn's law or Kaldor's law, which asserts a positive feedback relation between output growth and productivity growth (see, for example, Kaldor, 1967). Expanding markets are likely to lead to high productivity growth because of economies of scale and induced innovations in technology and the organization of production. The productivity increase, in turn, may further expand the industry's market because of lowered relative price and/or better quality products. Our interest here is more narrow and focuses on linkage effects of sectoral productivity growth.
s The measurement of the rate of sectoral productivity growth is complicated by the fact that technical change often takes the form of the development of new products. In such cases, the proper procedure would be to use some sort of quality-adjusted or hedonic price index to measure the real output of a sector. In such a case, the change in sectoral coefficients used to measure $\pi$ would be correctly captured. The Bureau of Labor Statistics price indices used for sectoral deflators do not, unfortunately, always do this, and therefore there may be some biases in the measured values of $\pi$.

9 In this case, there is no need to zero out the diagonal and matrix $A$ can be used instead of $A^{\circ}$.

10 There are some accounting difficulties with this approach. First, the sectoring of the capital matrix $K$ is the same as that of the interindustry flow matrix $A$. As a result, it is not possible to segment the R\&D expenditure performed by sector $i$ into a portion dedicated to capital goods and a residual dedicated to material inputs. Second, in the Terleckyj approach, it is not possible to identify the sales of capital goods produced by sector i to each
sector $j$. Therefore, an alternative RDKIND measure cannot be devised corresponding to RDMINDA.

11 Moreover, because of the high correlation between RDMIND and RDKIND, of the order of 0.7 , we usually used a separate specification for each. 12 The six total flow input-output tables are the standard 85 -order Bureau of Economic Analysis version (see U.S. Interindustry Economics Division (1984), for example). Details on labor coefficients, capital coefficients, depreciation rates, sectoral price indices, and other data adjustments can be found in the Appendix to Wolff (1985). Data on hours worked by sector, though the preferable measure of labor input to employment, were not available by sector and year and therefore could not be incorporated. A refinement, suggested by Schankerman (1981), is to net out the inputs used in the R\&D activity of each industry in order to avoid double-counting. Though possible for 1947 and 1958 , this procedure was not possible for the other years because of insufficient data and was therefore not done.

13 Utilization rates for 1947 were obtained from the Brandeis Economic Research Center. Those for other years were obtained from the Wharton School of Finance and Commerce's "Capacity Utilization Index" series. The variable K is then the utilized capital stock, measured as the net stock of fixed capital (plant and equipment) multiplied by the utilization rate. 14 The exceptions were SIC 20, 30, and 32, whose series ran fron 1957 to 1975, and SIC 37, whose series began in 1956. For documentation on data sources and methods, see Nadiri (1980). 15 Terleckyj's 1980 paper supports this conjecture. With a two-factor TFP index, the coefficient on direct (private) $R \& D$ is 0.27 , significant at the lis level; with a three-factor TFP index, the coefficient is 0.20 but is not statistically significant (Table 6.6, p. 375).

16 Results for RDMINDA are similar.

17 It is likely that the spillover effects from R\&D embodied in the new capital stock are understated. The reason is that RDKIND is measured according to net investment flows (i.e., the change in net capital stock). It is probable that borrowed $R \& D$ is more strongly related to gross investment, since replacement investment may also embody new technology. Data limitations prevent us from using the gross investment measure.

18 We also investigated two other sources of borrowed R\&D. The first is "second-round" borrowings of R\&D by sector $j$ from sector 1 . This is estimated by $\Sigma_{1} \Sigma_{k} a_{i x} a_{1} R D_{1} / x_{j}$. This tern would thus, for example, capture the computer sector's (i) R\&D which, through sales of computers to telecomunications (k) and of telecommancations to the sales sector ( $j$ ), is indirectly embodied in sales output. Second-round R\&D transfers are likely to be extremely weak and, indeed, are found to be statistically insignificant in our regression analysis. The second are "backward" spillovers from R\&D. The argument for this is that technology developed by industry $j$ may create new technological knowledge and opportunities for supplying industries. In particular, it may induce the development of new technology or products in the supplying industries. We developed several measures of backward spillovers, but none are found to be statistically significant.

19 See, for example, Terleckyj (1974), Nadiri (1977), Griliches (1980a), Levy and Terleckyj (1981), Lichtenberg (1984), and Griliches (1986). 20 A variant uses the coefficients $a^{*}{ }_{1 j} / \Sigma_{j} a^{*}{ }_{11}$, which shows the importance of input i exclusively among other intermediate inputs. Results are similar to those of LINKl.

21 No time dumy variables are included in this case, since there are no clear period-specific effects in this case.

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## Table 1

## Alignment of 87-Order Input-Output Sectors to SIC Codes in Manufacturing



Code
20

21
22,23
24

25

Name

Processed Foods

Tobacco Products

Fabrics, Textiles, and Apparel
Lumber and Wood Products 20-21

Furniture
Paper and Paper Products
Printing and Publishing
Chemicals and Related Products 27-30
Petroleum Refining 31
Rubber Products . 32
Leather and Footwear 33-34
Glass, Stone, and Clay Products 35-36
Primary Iron, Steel, and Nonferrous Metals 37-38
Metal Products $39-42$
Engines, Machinery, and Industrial Equipment 43-52
Electrical Machinery and Appliances $53-58$
Motor Vehicles and Transportation Equipment 59-61
Scientific Equipment and Supplies 62-63
Miscellaneous Manufacturing 64

22-23 24-25

26

15
16-19
Input-Output
Sectors
14

Table 2
Mean Values and Correlation Coefficients of Key Variables For Manufacturing Industries, 1947-1977*

|  | TFPGRT | RDGD0 | Embod |  |
| :---: | :---: | :---: | :---: | :---: |
| SIC | TFP Growth | R\&D/GDO |  |  |
| Code - Name | (\% per year) | (percent) | RDMIND | TFPIND |


| 20 Processed Foods | 0.78 | 0.181 | 0.0013 | 0.0030 | 0.0045 | 2.350 |
| :--- | ---: | :--- | :--- | :--- | :--- | :--- |
| 21-Tobacco Products | 0.88 | 0.204 | 0.0011 | 0.0002 | 0.0048 | 1.337 |
| 22,23-Textiles \& Apparel | 1.31 | 0.054 | 0.0029 | 0.0051 | 0.0082 | 2.916 |
| 24-Lumber, Wood Producțs | -0.17 | 0.130 | 0.0021 | 0.0014 | 0.0021 | 2.275 |
| 25-Furniture | 0.23 | 0.115 | 0.0032 | 0.0009 | 0.0036 | 1.078 |
| 26-Paper, Paper Products | 0.30 | 0.498 | 0.0039 | 0.0067 | 0.0030 | 3.035 |
| 27-Printing, Publishing | 0.01 | 0.279 | 0.0027 | 0.0046 | 0.0032 | 2.140 |
| 28-Chemicals | 1.86 | 2.493 | 0.0098 | 0.0129 | 0.0057 | 4.269 |
| 29-Petroleun Refining | 0.61 | 1.272 | 0.0027 | 0.0028 | -0.0031 | 2.305 |
| 30-Rubber Products | 1.47 | 1.107 | 0.0074 | 0.0035 | 0.0057 | 2.020 |
| 31-Leather and Footwear | 0.51 | 0.260 | 0.0033 | 0.0003 | 0.0047 | 1.345 |
| 32-Glass,Stone, Clay Prod | -0.09 | 0.877 | 0.0035 | 0.0032 | 0.0024 | 1.770 |
| 33-Prinary Metals | -0.04 | 0.527 | 0.0052 | 0.0205 | -0.0011 | 4.756 |
| 34-Metal Products | 0.13 | 0.588 | 0.0059 | 0.0050 | 0.0016 | 2.657 |
| 35-Machinery, Ind. Equip. | 0.46 | 2.782 | 0.0124 | 0.0088 | 0.0033 | 2.793 |
| 36-Elect. Machinery | 1.59 | 7.858 | 0.0168 | 0.0096 | 0.0047 | 2.381 |
| 37-Transport Equipment | 0.62 | 9.574 | 0.0273 | 0.0096 | 0.0039 | 2.441 |
| 38-Sciantific Equip. | 1.29 | 4.607 | 0.0126 | 0.0018 | 0.0046 | 1.357 |
| 39-Miscellaneous Manuf. | 0.61 | 0.223 | 0.0050 | 0.0011 | 0.0036 | 1.330 |
|  |  |  |  |  |  |  |
| Unweighted Average | 0.65 | 1.770 | 0.0068 | 0.0053 | 0.0034 | 2.345 |
| Weighted Average | 0.72 | 2.413 | 0.0090 | 0.0074 | 0.0036 | 2.739 |
| Correlation with TFP Growth | -- | 0.39 | 0.34 | 0.08 | 0.60 | 0.07 |

## Averages of Groups Ranked by TFPGRT

| Top 5 | 1.50 | 3.224 | 0.0099 | 0.0066 | 0.0058 | 2.589 |
| :--- | ---: | ---: | ---: | ---: | ---: | ---: |
| Next 5 | 0.70 | 2.291 | 0.0075 | 0.0033 | 0.0027 | 1.953 |
| Next 5 | 0.33 | 0.849 | 0.0057 | 0.0043 | 0.0032 | 2.182 |
| Bottom 4 | -0.07 | 0.453 | 0.0034 | 0.0074 | 0.0017 | 2.735 |

a. The figure shown for TFPGRT is the average annual rate of TFP growth over the 1947-77 period. For RDGDO, RDMIND, RDKIND, and LINK2, the figure shown is the unweighted average value of the variable in 1947, 1958, 1963, 1967, 1972, and 1977. For TFPIND, the figure shown is the unweighted average value of the variable in five periods: 1947-58, 195863, 1963-67, 1967-72, and 1972-77.
b. Weighted by gross output shares.

Table 3
The Effect of R\&D Intensity, Borrowed R\&D and Borrowed TFP on the Sectoral Rate of TFP Growth

| Dependent Variable: TFPGRT |  |  |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Independent Variables |  |  |  |  |  |  |  |  |
| Constant | $\begin{aligned} & 0.0041 \\ & (1.33) \end{aligned}$ | $\begin{aligned} & 0.0084^{\star *} \\ & (2.07) \end{aligned}$ | $\begin{aligned} & 0.0047 \star \\ & (1.42) \end{aligned}$ | $\begin{aligned} & 0.0029 \\ & (0.99) \end{aligned}$ | $\begin{gathered} 0.0 \\ (0.01) \end{gathered}$ | $\begin{aligned} & -0.003 \\ & (0.07) \end{aligned}$ | $\begin{aligned} & -0.001 \\ & (0.27) \end{aligned}$ | $\begin{aligned} & -0.0003 \\ & (0.07) \end{aligned}$ |
| RDGDO | $\begin{aligned} & 0.106 * * \\ & (2.21) \end{aligned}$ | $\begin{aligned} & 0.103^{\star \star} \\ & (2.39) \end{aligned}$ | $\begin{aligned} & 0.111 * * \\ & (2.26) \end{aligned}$ | $\begin{aligned} & 0.106 \star \star \\ & (2.28) \end{aligned}$ | $\begin{aligned} & 0.188 * * \\ & (2.31) \end{aligned}$ | $\begin{aligned} & 0.173^{* *} \\ & (2.13) \end{aligned}$ | $\begin{aligned} & 0.208 * * \\ & (2.53) \end{aligned}$ | $\begin{aligned} & 0.189 \star \star \\ & (2.31) \end{aligned}$ |
| RDMIND |  | $\begin{aligned} & 0.143 \\ & (1.59) \end{aligned}$ |  |  |  | $\begin{aligned} & 0.076 \\ & (1.23) \end{aligned}$ |  |  |
| RDKIND |  |  | $\begin{aligned} & -0.008 \\ & (0.51) \end{aligned}$ |  |  |  | $\begin{aligned} & 0.092 * \\ & (1.73) \end{aligned}$ |  |
| TFPIND |  |  |  | $\begin{aligned} & 0.889 \star * \\ & (2.48) \end{aligned}$ |  |  |  | $\begin{gathered} 0.114 \\ (0.25) \end{gathered}$ |
| $\mathrm{R}^{2}$ | 0.222 | 0.244 | 0.224 | 0.273 | 0.062 | 0.070 | 0.075 | 0.063 |
| $\bar{R}^{2}$ | 0.179 | 0.193 | 0.172 | 0.224 | 0.041 | 0.049 | 0.050 | 0.037 |
| Std. <br> Error $\sigma$ | 0.0125 | 0.0124 | 0.0126 | 0.0122 | 0.0243 | 0.0243 | 0.0242 | 0.0244 |
| Sample ${ }^{\text {b }}$ | Manuf. | Manuf. | Manuf. | Manuf. | All | All | All | All |

[^1]Table 4
Spillover and Linkage Effects of Private R\&D*

| Dependent Variable: |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Independent Variables | TRPGRT | TFPGRT | TFPGRT | TFPGRT | LINK1 | LINK2 |
| Constant | $\begin{aligned} & 0.0026 \\ & (0.85) \end{aligned}$ | $\begin{aligned} & 0.0028 \\ & (0.98) \end{aligned}$ | $\begin{aligned} & -0.0006 \\ & (0.17) \end{aligned}$ | $\begin{aligned} & -0.0013 \\ & (0.36) \end{aligned}$ | $\begin{aligned} & 0.0099 * * * \\ & (15.56) \end{aligned}$ | $\begin{aligned} & \star \quad 2.004 \star \star * \\ & (29.83) \end{aligned}$ |
| RDPGDO | $\begin{aligned} & 0.430 * * * \\ & (2.95) \end{aligned}$ | $\begin{aligned} & 0.378 * * * \\ & (3.21) \end{aligned}$ | $\begin{aligned} & 0.612 \star \star \\ & (2.46) \end{aligned}$ | $\begin{aligned} & 0.589 * * * \\ & (3.21) \end{aligned}$ | $\begin{aligned} & 0.243 * * * \\ & (3.62) \end{aligned}$ | $\begin{aligned} & 17.52 \star * \\ & (2.53) \end{aligned}$ |
| RDGGDO | $\begin{aligned} & -0.072 \\ & (0.81) \end{aligned}$ |  | $\begin{aligned} & -0.087 \\ & (0.50) \end{aligned}$ |  |  |  |
| RDPMIND |  | $\begin{aligned} & 0.171^{\star} \\ & (1.72) \end{aligned}$ |  |  |  |  |
| RDPKIND |  |  |  | $\begin{aligned} & 0.105 * * \\ & (1.98) \end{aligned}$ |  | : |
| $\mathrm{R}^{2}$ | 0.268 | 0.281 | 0.076 | 0.090 | 0.048 | 0.027 |
| $\mathbf{R}^{\mathbf{2}}$ | 0.218 | 0.234 | 0.051 | 0.065 | 0.041 | 0.023 |
| Std. <br> Error a | 0.0122 | 0.0120 | 0.0242 | 0.0240 | 0.0082 | 0.919 |
| Sample ${ }^{\text {b }}$ | Manuf. | Manuf. | All | All | All | All |

[^2]Table 5

The Effect of R\&D Intensity and Productivity Growth on Forward Linkage Structure ${ }^{\text {a }}$


[^3]
## SEVILLA INTERNATIONAL CONFERENCE

 ON INPUT-OUTPUT TECHNIQUES
# THEORETIGAL BASE OF EDUCATION-ECONOMY NEXUS AND METHODOLOGY FOR ACCOUNTING OF LINKAGE-EFFECT IN AN INPUT-OUTPUT FRAMEWORK 

By<br>SHRI PRAKASH AND TARUJYOTI BURAGOHAIN

SESSION : TRANSFORMATION, INTEGRATION AND STRUCTURAL ADJUSTMENT•

NATIONAL INSTITUTE OF EDUCATIONAL PLANNING AND ADMINISTRATION, 17-B, SRI AUROBINDO MARG, NEW DELHI - 110 016. (INDIA)

# THEORETICAL BASE OF EDUCATION-ECONOMY NEXUS AND METHODOLOGY FOR ACCOUNTING OF LINKAGE-EFFECT IN AN INPUT-OUTPUT FRAMEWORK 

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## (Abstract)

Pivotal role of education in economic growth has been recognised for long. Economic effects of education comprise of both direct and indirect components. Though spill-over effects of education have been recognised universally, yet such effects have neither been incorporated in the analytical core nor have these been measured and quantified. Concept of economic value of education in vogue is too narrow to encompass all economic effects of education. This study seeks to fill-up these conceptual gaps and methodological ifitations of economic analysis of education. Backward, forward and residentiary linkage effects of education on economy have, however, been totally neglected. These effects may be captured by an analysis of educationeconomy inter-relations in input-output framework:

Four input-output models for delineating education-economy nexus have been developed to measure direct and indirect output/income; productivity and employment effects of education. Linkage effects represent the missing elements of accounting of output/income and employment effect of education on growth. The models have been tested empirically for 1959, 1969, and 1979. Empirical results show income and employment effects of education to be considerable. The results highlight inadequacy of conventional concept of economic value of education and limitations of traditional methodology of determination of the contribution of education to economic growth in a static framework.

## 1. INTRODUCTION

Walsh (1935), Friedman and Kuznets (1945), Leontief (1966), Mincer (1958) and Schultz (1964) have empirically and theoretically highlighted the role and contribution of education to economic growth. Differential life-long earnings, reflecting productivity differences, have conventionally been considered to measure economic value, and

[^4]hence, income/growth effect of education. Differential earnings are, however, conceptually far too narrow and inadequate to encompass economic effect of education in totality. Effect refers to overall ultimate changes in variate values in response to external stimuli. Overall ultimate changes include (i) direct and indirect changes, on the one hand, and (ii) immediate or short-run and long run or ultimate changes in endogenous variable(s), on the other. Changes in endogenous variables occur in response to changes in exogenous factor(s). Effect of education upon an economy should, therefore, refer to both direct and indirect, and immediate and ultimate effects in the instant and long runs. Though economists have recognised spill-over and indirect effects of education, such effects have not been incorporated in analytical core. Consequently, these effects have neither been measured nor have these been quantified.

Education-economy inter-relations may be analysed in an inputoutput frame-work. Endogenisation of education in input-output model(s) will facilitate the determination of instant and ultimate as well as direct and indirect effects of education on economy (Cf. Correa and Tinbergen, 1963, Stone, 1966, Prakash, 1971, 1976, 1977, 1989). We will, however, focus mainly on such economic effects of education as are theoretically important, empirically measurable and over-looked by analysts so far.

Education promotes growth directly and indirectly. Scientific and - technological research and development reflect the most decisive effect of education on an economy. Leontief (1966) resolved his paradox by according implicit recognition to $R$ and $D$ effect of education on growth. $R$ and $D$ effect of education on technological upgradation of production base of US economy made American human capital
much more productive than that of the rest of the world. Leontief showed these productivity differentials of human capital to account for relatively higher labour intensity of US exports.

Education generates income through employment of educated manpower and its productivity effect on output. Income effect of education, activated through employment, comprises of two components : (i) earnings of those employed in education. Education emploies very high proportion of educated manpower in developing economies like the Indian one. Then, the growth of numerous local/regional economies and backward regions of the developing countries are propped-up and propelled by backward linkage effect of education on growth, specially colleges and universities, accounting for significant proportions of employment and income of the economies of locations of educational institutions; and (ii) aggregate of earning differentials of educated employed in social and production sectors of local/regional economies account for substantial proportion of disposable income of local/regional economies. Training and education, that is, knowledge, skills and information enhance productivity of human capital. The productivity gains reflect differential earnings of manpower.

Education generates income indirectly through its output and employment effects also. Indirect effect comprises of two components : (i) disposal of earnings on consumption by those employed in education, activating multiplier process of growth which, in turn, generates secondary rounds of employment and income, and (ii) demand for output of commodity sectors for use as intermediate inputs in educational production in highly dispersed locations which generate (a) income and (b) employment in sectors having forward linkages with
fucation. Such industries at local and regional levels become able due to locally/regionally dispersed growth of education. These mponents, except differential earnings, have been totally neglected conventional accounting of income and employment effect of jcation.

Such linkage effects of education on economy may be captured by sut-output analysis of education-economy interrelations by 'ogenising education in Leontief's model. Backward and forward kages of education with the growing economy in a dynamic state may, aver, be analysed by dynamic linkage accounting (Prakash, 1986). MODEL

Model I : STATIC MODEL
Conceptual and methodological base of the models has been loped by senior author in earlier studies (Prakash and Buragohain, , Prakash and Chowdhury, 1990).

Let there be $m+k=n$ sectors, of which $p=1,2, \ldots, m$, are retion sectors, and $e=(m+1),(m+2) \ldots, n$, are education sectors; lucation sectors will thus range from $m+1$ to $n$. Output of ction sectors will satisfy inter-industry and final demand, ding investment demand, emanating both from production and tion sectors. Education, that is, knowledge, information and i, used in commodity production sectors of the economy is ed in manpower deployed for production and $R$ and $D$ activities. $R$ 1. embodies technology; machinery and plants are the carriers of logy. Similarly, human capital is the carrier of knowledge, -and information. Demand for education, emanating from tion sectors, will thus coincide with demand for human capital. ration is not demanded for consumption, demand for education
either as intermediate or final use will otherwise be zero. This assumption is implicit. Output of education has to satisfy interindustry demand, emanating from education sector itself, and final demand.

The technology matrix-A is an augmented matrix with corresponding augmentation of.gross-output and final-demand vectors. Technology matrix - $A(1)$, final demand vector $f(1)$ and gross output vector - $X$ have been augmented and partitioned accordingly :


This decomposable triangularised system represents two subsets of structural equations, corresponding to two sub-economies which may be solved iteratively Dorfman, Samuelson and Solow 1958, Prakash and Chowdhury, 1990) :
$X(e)=[I-A(e \theta)]^{-1} f(e)$
and

$$
\begin{equation*}
X(p)=[I-A(p p)]^{-1} A(p e)[I-A(e \theta)]^{-1} f(e)+[I-A(p p)]^{-1} f(p) \tag{2}
\end{equation*}
$$

2.2 Model II: GENERALISED STATIC MODEL

The model may be generalised by eliminating triangularisation of the partioned matrix, $A(1)$. Education will, however, include the dissemination of information and knowledge about family planning, agricultural extension, councelling, engineering and industrial consultancy, and in-service training, making sub-matrix $A(e p)$ nonzero. Matrix $A(1)$ and model - I will then lead to $A(2)$ of model-II :

$A(2)=$| - |  |
| :---: | :---: |
| $A(p p)$ | $A($ pe $)$ |
| $A(e p)$ | $A(e e)$ |
|  |  |

Iterative solution will then be
$X(e)=[I-A(e e)]^{-1} A(e p) X(p)+[I-A(e e)]^{-1} f(e)$
and
$X(p)=S^{-1}+S^{-1} U+S^{-1} E=S^{-1}(I+U+E)$
where
$S=\left[I-\left\{[I-A(p p)]^{-1} A(p e)[I-A(e e)]^{-1} A(e p)\right\}\right]$
$U=[I-A(p p)]^{-1} A(p e)[I-A(e e)]^{-1} f(e)$, and $E=[I-A(p p)]^{-1} f(p)$
2.3 Model - III : DYNAMIC MODEL

Above models may be transformed into a dynamic and generalised model by incorporating triangularised augmented capital matrix, $B$ corresponding to triangularised augmented matrix-A. An underlying assumption will be that output of education, that is, knowledge and information, is not storable, leading to stock sub-matrix $B(e p)$ to be zero:
$B(1)=\left\{\begin{array}{l:c}- & B(p p) \\ \hdashline 0 & B(p e) \\ 1- & B(e e) \\ & \end{array}\right.$

Output of production sectors has now to satisfy its own interindustry, investment and final demand, on the one hand, and interindustry and investment requirements of education, on the other. Output of education has to satisfy its own inter-industry, investment and final demand besides the manpower requirements of production and education sectors. Maintenance of employment at current levels in future is similar to the maintenance of physical capital at levels accumulated in the past and brought forward into the present though incremental employment may be treated like current investment as addition to already accumulated stock of human capital. $B(e e)$ may
differ from $B(p e)$ in dimensions. Iterative solution of two sub-sets of dynamic structural equations with triangularised matrices $A$ and $B$ will be as follows:
-1
$X(e)=[I-R] \quad f(e)$
and
$X(p)=[I-C]^{-1} D X(e)+[I-C]^{-1} f(p)$
where
$C=A(p p)+B(p p) G$,
$D=A(p e)+B(p e) G$,
$R=A(e e)+B(e e) G, G$ is the matrix of growth rates. In case of balanced growth, all sectors of the economy will grow at the same constant rate. Hence,
$G=G(p)=G(e)=s c a l a r$ for all $p$ and e.
If production sectors grow at different rates, education will also grow differently. Growth of two sub-systems has to be conformable and consistent. Two diagonal submatrices $G$, one each for education and production sub-economies, will apply.
2.4 Model IV : GENERALISED DYNAMIC MODEL

Like the generalisation of partitioned triangular matrix-A(1), corresponding matrix-B(1) will be augmented by generalisation and extension of the concept of human capital for encompassing human resources engaged in consultancy and extension. The partitioned triangular matrix- $B(1)$ will be replaced by $B(2)$ :

$B(2)=$| - | $B(p p)$ |
| :--- | :---: |
| $B($ ep $)$ | $B($ ee $)$ |

This will lead to the endogenisation of employment in all sectors of the economy. Following solution sub-sets of mode will hold :

$$
\begin{equation*}
X(e)=[I-R]^{-1} A(e p) X(p)+[I-R]^{-1} B(e p) G X(p)+[I-R]^{-1} f(e) \tag{7}
\end{equation*}
$$

and
$X(p)=Z^{-1}+Z^{-1} V+Z^{-1} W+Z^{-1} Q=Z^{-1}(I+V+W+Q)$
where

2.5 ECONOMIC EFFECTS OF EDUCATION

### 2.5.1 OUTPUT EFFECT

Effects of education may broadly be classified into two types :
(a) output effect, and (b) employment effect. Output effect will generate income effect while employment effect will generate productivity effect. Output effect of education, corresponding to model-I, is determined as follows :
$Y(e 1)=[I-A(p p)]^{-1} A(p e)[I-A(e \theta)]^{-1} f(e)$
Output effect of education dontes the backward linkage ef.fect of education upon gross output of commodity sectors. It, therefore, corresponds to indirect output effect of education upon output. $\quad Y(e 1)$ coincides obviously with the first part of equation (2) of the solution value of $X(p)$. The output effect of education, corresponding to models II, III and IV respectively are derived analogously.

### 2.5.2 INCOME EFFECT

Income effect of education is measured by value-added in educational production. Value-added refers to the excess of money value of output over money value of commodity inputs used-up in production. Students enter education either as raw-materials or semi-
finished or intermediate inputs in production. Education produces knowledge, skills and information. Value-added by education represents the addition to the stock of knowledge possessed by students at the time of their entry in a given course/stage of education. Knowledge-added is thus the difference between the stock of knowledge possessed by students at the time of entry and the stock of knowledge possessed at the time of exit from education. This may analogously to 'value-added' be called 'knowledge-added'. The valueadded by education will thus be the money value of knowledge-added by education. Value-added will be given by $\begin{aligned} \text { Value-added } & =\{(\text { Gross money value of output during entire life-span) } \\ & -[(\text { money value of current commodity inputs during entire } \\ & \text { period of education) }+ \text { (money value of inputs of } \\ & \text { students'time into educational production processes)]\}/T }\end{aligned}$
where $T$ is total ife span over which earnings are spread. In annual accounting of growth, only current year's value added may be considered. Students are obviously the carriers of knowledge-added. Knowledge and skills added by education are carried forward by students into work-place on employment. Gross value of educational output will, therefore, equal the present value of differential ifelong earnings of people with given level and type of education. Sum total of earnings expected to accrue to individuals throughout ife will be discounted by an appropriate rate for converting future/expected earnings into their present value. Conventionally, earnings during working life span alone are reckoned. This implies under-estimation of returns to education since earnings continue to flow even after retirement. Retirement benefits represent the deferred payments of earnings earned during the working life-span. Pensionary benefits continue to accrue to the dependents, specially
the surviving spouse, even after the death of the earner. This component has consistently been neglected in conventional estimates of economic value of education.

Value of inputs of students' time into educational production measures opportunity cost. Value of students' time used-up in educational production, that is, in learning and acquisition of knowledge is estimated in a slightly different manner. Students, having finished a lower stage of education, enter as intermediate inputs into the production process of next higher level of education. Students stay in a level of education only for the period required for its completion. So, value of students' time as an intermediate input is reckoned only for the duration of the given educational process/course. It may be estimated as number of students enrolled in a given level of education multiplied by the duration of the course which is again multiplied by annual average wage/earning rate at which people with that level of education immediately preceding the given course/level of education are employed. Money value of commodities used-up as intermediate inputs in production of given education will also be subtracted from the money-value of output for determing valueadded of incremental knowledge of given educational level. Thus, value-added of education requires double rather than single subtraction. Division of the difference of these three figures thus arrived by total earning span will furnish annual income imputeable to education.

Differential earnings, imputeable to various levels and types of education, are estimated from cross-section data relating to age-education-earning profiles. Part of these differential earnings are, therefore, attributeable to experience and on-the-job training. It
may, therefore, be desirable to base the estimates of differential earnings, imputeable to educational differences, on age-educationearning profiles of newly employed persons, having no previous experience and on the job training. Estimates of life-long earnings from cross section data are based on assumptions of invariance of (i) age, (ii) education, and (iii) earning mixes through time, education specific mean annual earnings may, however, serve the purpose better as a first approximation (Cf. Hussain, 1969).

Partitioned value-added vector of above models will be
$V=[V(p) ; V(e)]$
where $V(p)=V(p) \times(p)$, and $V(e)=V(e) X(e)$.
$V(p)$ will have two alternative solutions, corresponding to static and generalised static models.

Solution I may be designated $V(p 1)$ :
$V(p 1)=V(p 1)\left\{[I-A(p p)]^{-1} A(p e)[I-A(e e)]^{-1} f(e)+[I-A(p p)]^{-1} f(p)\right\}$ $=v(p 1)[I-A(p p)]^{-1} A(p e)[I-A(e e)]^{-1} f(e)+V(p 1)[I-A(p p)]^{-1} f(p)$ $=V(p e)+V(p p)$
where
$V(p 1)=P-P A(p p)=$ per unit value-added vector. $P$ is vector of prices of inputs of commodity sectors;
$V(p p)=$ value-added of production sectors independent of interaction effects of education;
$V(p e)=$ value added of production sectors induced by linkage effect with education.

Solution II may be designated $V(p 2)$ :
$\begin{aligned} V(p 2)= & V(p 2)\left\{I-[I-A(p p)]^{-1} A(p e)[I-A(e e)]^{-1} A(e p)\right\}+V(p 2)\{[I- \\ & \left.A(p p)]^{-1} A(p e)[I-A(e e)]^{-1} f(e)\right\}+V(p 2)\left\{[I-A(p p)]^{-1} f(p)\right\}\end{aligned}$
where $v(p 2)=P-P A(p p)-P A(e p)$, and
$V(e)=\left\{[V(p 2)-[P A(p e)+W A(e e)]\}\left[I-A(e e)^{-1}\right] f(e)\right.$
where $v(p 2)$ is the vector of value-added per unit of output of education and $W$ is the vector of unit opportunity cost of stay in education. Opportunity cost equals earnings foregone. Education's contribution to economy is thus conventionally under-estimated by an amount equaling $V(p e)$. Another source of under-estimation of incomeeffect of education is the exclusion of retirement benefits.

### 2.5.3 EMPLOYMENT EFFECT

Education affects employment both directly and indirectly. Indirect employment effect of education has also been neglected so far. This limitation can, however, be mitigated easily. Education specific employment vector, $N$ may be partitioned to correspond with to components of gross-output vector. It will furnish following solution values of employment :
$N=$

where $L(p)$ and $L(e)$ are sub-matrices of education specific employment coefficients respectively corresponding to two sub-economies. $X(p)$ and $X(e)$ are solution values of gross output vector.

Solution values of employment sub-vectors $N(p)$ and $N(e)$ depend directly upon the solution values of output sub-vectors $X(p)$ and $X(e)$ which will differ from model to model. Solution values of employment vectors corresponding to static models will be the following :

```
N(p)=L(p)[I-A(pp)] A(pe)[I-A(ee)] f(e) +L(p)[I-A(pp)]ff(p)
    =N(pe) +N(pp)
\(N(e)=N(e e)+N(p e)\)
\(N(e e)=L(e)[I-A(e e)]^{-1} f(e)\)
where \(N(e e)\) is education specific employment generated by education, \(N(p e)\) is indirectly generated education specific employment in production sectors of the economy, \(N(p p)\) is education specific employment generated directly in production sectors, and \(N(e)\) is total employment generated by education.

The solution values of employment vector corresponding to generalised static and dynamic models will be derived by substitution of output vectors derived from those models analogously into employment related equations if human capital is treated differently from physical capital. In the generalised dynamic model, solution values of employment vector will not be required separately otherwise. Sub-matrices \(B(e p)\) and \(B(e e)\) will be augmented by incorporation of human capital coefficients, First sub-set of \(B(e e)\) will be diagonal in structure, diagonal elements will consist of coefficients of students enrolled in different processes, carried forward as stocks from one to another period; second subset of elements of \(B(e e)\) will consist of teachers and other staff, carried forward as stocks per unit of educational output. Elements of \(B(e e)\) may be ordered to furnish employment part of solution in an identifiable and separable form. Employment in both sub-systems will emerge as solution values of output vectors, implying corresponding augmentation of output vector as well.

Employment effect of education in model I will be
\(N(e)=L(p)\left\{[I-A(p p)]^{-1} A(p e) f(e)\right\}+L(e)[I-A(e e)]^{-1} f(e)\) (17)
Linkage effect of education on income through employment in production sectors will be
\(L(p) Y(e)=L(p)\left\{[I-A(p p)]^{-1} A(p e)[I-A(e \theta)]^{-1} f(e)\right\}\)

Solutions of generalised static and generalised dynamic models may be derived analogously.
3. Empirical Results

Empirical results have been organised into distinct sections according to the model from the application of which these results have been obtained.

\subsection*{3.1 Data Base}

Twenty-nine by twenty-nine input-output matrix (Gupta and Talwar) for 1959 has been aggregated into \(7 \times 7\) matrix in order to make it conform to the basic conceptualisation of Mahalanobis model. As against this, \(60 \times 60\) input-output matrices of CSO for 1969 and 1979 have been aggregated into \(37 \times 37\) matrices in order to match them with the capital coefficients matrix of Datta-Majumdar.

Education has been divided into three highly aggregative subsectors for 1959 : education upto matriculation level, under-graduate education including higher-secondary and intermediate levels and education of graduàte and above graduate levels. However, 82 individual educational activities (classes) have been distinguished for 1969 and 1979. Solutions of purely paediometric 'educational production processes have been worked out for this highly disaggregative sub-system of educatión. Results have, however, been aggregated into eight sub-sectors of education for which the direction and magnitudes of education-economy linkages have also been determined by first production sub-model(s). These seven sub-sectors are as follows : (i) primary, (ii) middle, (iii) high school, (iv) higher secondary school, (v) teachers' training, (vi) general education of
college level, (vii) professional education of college level, and (viii) university level education. But general and professional education of college level have been combined together in \(7 \times 7\) matrix. Besides above seven educational levels, two additional categories of 'illiterate's and 'literates without formal education' have also been considered for classification of employment according to educational attainments.

Socio-Economic tables of Census reports of 1961, 1971 and 1981 and data from Economic Survey, Govt. of India, and OccuptionalEducational Pattern of Employment in Public and Private Sectors, Govt. of India, of relevant years have been used to estimate sectoral and educational distribution of employment. Economic Survey excludes employment in establishments not covered by Factories Act. Ratios of aggregative sector-wise Census employment for 1961, 1971 and 1981 to employment in corresponding Economic Survey sectors have been used to determine total sectoral employment in private and public sectors taken together for 1959, 1969 and 1979. It is thus implicitly assumed that the ratios of.Census to Survey employment for 1961,1971 and 1981 will be valid 'to 'generate' estimates of total sectoral employment' for 1959, 1969 and 1979. Total employment in each aggregative Economic Survey/Census sector has then been distributed into sub-sectors constituting each of these broad aggregative sectoral categories according to the employment patterns in Private and Public Sectors, on the one hand, and the sub-sectorl patterns of main and marginal workers in census reports, on the other. Disaggregated sectors for which Occupational Pattern reports employment exceed sectors into which economy is classified in input-output tables. Sectoral
employment has to be suitably aggregated into 36 production sectors for matching sectoral classification of input-output matrices. One education sector of input-output matrices has, however, been disaggregated into seven aggregative sub-sectors mentioned above. Employment in 36 production and 7 educational sectors has then been classified in nine educational categories according to distribution norms in Employment Pattern. As against employment in production sectors, employment in seven sub-sectors of education has been estimated from data relating to employment of teachers reported in Education in India, Department of Education, Govt. of India, whereas non-teacher employment has been estimated from data and norms used by Panchamukhi and Hussain.

\subsection*{3.2 Solution of Static Model}

The solution of the static model has been derived for 1959, 1969 and 1979 separately in four components : (i) first component deals with the determination of output and output- effect of education, (ii) second component determines value-added/income-effect of education, (ịi) third component deals with the productivity-effect of education, and (iv) fourth component delineates the broad contours of employment and employment-effect of education,
3.2.1 Output-Effect of Education

Solution vector of sectoral gross output consists of three components : (i) output of the production sectors required to satisfy direct and indirect components of final demand for goods and services produced in production sectors, (ii) output required to satisfy intermediate demand, emanating from education sectors, for the goods and services produced by production sectors of the economy. This second component manifests the output-effect of backward linkages of
education with economy and forward linkages of the economy with education, overlooked so far in literature, and (iii) third and last component relates directly to economic value of human capital produced by education.

Solution values of different components of gross output and its sectoral distribution are reported in statistical appendix. Values of different components of gross output of the economy as a whole are reported in the following table:
(Rs. in Crores)
\begin{tabular}{|c|c|c|c|c|c|}
\hline Due to Pro & Commodity duction & Due to L with Educ & On Total E & Education Sector & Grand Total \\
\hline 1959 : Absolute & 16,779.38 & 36.45 & 16,815.83 & 1289.84 & 18,105.77 \\
\hline Relative Shares & 92.67 & 0.201 & 92.88 & 7.82 & 100.00 \\
\hline 1969 : Absolute & 49,387.27 & 1,651.37 & 51,038.65 & 2403.26 & 53,441.91 \\
\hline Relative Shares & 92.41 & 3.09 & 95.5 & 4.49 & 100.00 \\
\hline 1979 : Absolute & 1,53,711.06 & 6,483.46 & 1,60,194.53 & 2703.42 & 1,62,897.95 \\
\hline Relative Shares & 94.36 & 3.98 & 98.34 & 1.69 & 100.00 \\
\hline
\end{tabular}

The solution values of sectoral gross output produced to satisfy final demand for goods and services of the production sectors of the economy approximate the observed values very closely, MAPE statistics having as low values as \(3.1,2.6\) and 0.8 per cent for 1959, 1969 and 1979, , years for which solutions of the static model have been workedout. First component of gross domestic output has, however, increased very rapidly from 1959 to 1979 , the growth has been decelerated considerably from sixties to seventies, annual growth rate having declined from 76.6 in sixties to only 12.02 per cent in seventies. The growth rates have, however, varied sharply among the sectors.

Output of goods and services produced to sat:sfy inter-industry
demand generated by educational development has increased much more rapidly than that component of output of goods and services produced for satisfying the intermediate and final demand of the economy itself. Output-effect of education has increased at 132.06 per cent per annum during sixties. The growth of output-effect of education has, however, declined to only 14.65 per cent per annum during seventies. But these growth rates of output due to backward inkages of education with economy are greater than the corresponding rates of growth of gross output to satisfy inter-industry and final demand for commodity sectors of the economy. The rapidly rising effect of education on output of production sectors of the economy is highlighted by the fact that the output-effect of education accounted for only 0.21 per cent of gross-output of the economy in 1959 which has risen to 3.24 per cent of gross output of 1969. The output-effect of education has been further intensified in seventies when it has increased to account for 4.05 per cent of gross output of 1979 . Thus, the acceleration of educational development has facilitated educationeffect to rise both absolutely and relatively.

Changes in output-effect of education has twin facets : (i) education, and hence, its output-effect has grown more rapidly than the production sectors of the economy, and (ii) like gross output of the economy, growth of output-effect of education has considerably declerated in seventies. The growth of output-effect of education over time, however, shows that the movement of the economy towards mature stages of growth leads to the deepening and widening of education-economy linkages. Rising income facilitates increased investment in education which, in turn, leads to the deepening and widening of the material-base of educational production, on the one
hand, and the strengthening of the round-about methods of production in economy as well as education, on the other. Education, in its turn, promotes the growth of production sectors partly by generating interindustry demand for goods and services produced by the production sectors through its backward linkages with the economy and partly by raising the levels of efficiency and productivity of human and physical capital. These twin facets of growth have led to an increase in the education-economy linkages in India.

Above results highlight the fact that the Indian economy has been structurally transformed in the process of growth. Agriculture has been the most dominant sector of the economy, followed by services next in importance, these two sectors have accounted for 52 and 20 per cent, whereas consumption goods sector have had a share of about 16 per cent in gross-output of the economy in 1959. structural transformation has facilitated a decline in the contribution of agriculture, including forestry and logging, from 52 per cent in 1959 to 35-37 per cent of gross-output of the economy in 1969/1979, while the share of tertiary sectors, has increased correspondingly. Emerging dominance of the Indian economy by tertiary activities and the accelerated growth of education have occurred concomitantly (Prakash, 1992).

Interestingly, shares of individual sectors in gross output of the economy and sectoral output-effects of education are directly related. The coefficient of rank-correlation between the proportion of gross-output of the economy accounted by an individual sectior and the proportion of gross-output of that sector accounted by outputeffect of education is as high as 0.57 in 1959, it has increased to
0.62 in 1969 while it emerges as high as 0.988 in 1979. Thus, the proportion of output of the economy accounted by an individual sector and the output-effect of education appear to have started moving in almost perfect unison by 1979.

At lower levels of income/output, an economy can not afford high investment in education. As the economy develops, the resource constraint to educational development is relaxed; educational development, in its turn, accelerates economic growth. Such sectors as have stronger forward and backward linkages with education grow more rapidly than others since relatively greater degree of productivity improvements and output-gains from education accrue to such sectors, leading to relatively higher increase in their shares in gross output of the economy. As against this, such sectors as have relatively greater weight in the output of the economy have the potential to derive greater shares in productivity-gains and outputeffects from education provided that the knowledge base of production is sufficiently strengthened. It is these facets of education-economy inter-relations that account for the ascendancy of tertiary and decline of agriculture and other primary activities in economic structure of India through time.

The output-effect of education has varied sharply among sectors leading to the structural transformation of the economy. Output effect of education on tertiary sectors is 1 percent of gross-output of services. Output-effect of education on mining and machinery sectors has been the least in 1959. Backward linkages of education with services sectors have accounted for almost half of the overall output-effect of education on the economy, while heavy investment and consumption goods sectors have together accounted for nearly one third
of total output of the economy in 1959. The diversification of economic structure, technological up-gradation of production base of both education and economy and the relaxing of resource and educated manpower constraints to growth seem to have enhanced the output-effect of education through time.

Sectoral patterns of gains in growth have changed in the process of development. Agriculture and forestry have increased their share to 2.21 per cent of overall gains in gross-output in 1969, which has further risen to 4.5 per cent in 1979, whereas the share of mining and quarrying in output effect of education has decined from 1.5 in 1969 to 0.03 in 1979. Backward dependence of education upon agriculture has thius increased substantially and backward linkages of agriculture with education have also been greatly strengthened in the wake of green revolution. In the early stages of development of agrarian economies, food requirements of students may constitute the major proportion of the maintenance cost of students. Rapid growth of output of foodgrains will, therefore, stimulate demand for education while productivity gains from green revolution will facilitate the release of child-labour from agriculture to accelerate human capital accumulation (Cf. Brahmanand, 1992, Cf. Prakash and Chaubey, 1992). Share of tertiary activities in output-effect of education has, however, increased even more rapidly, it having risen to about 60 per cent of education's overall effect on economy in 1979. Tertiary led growth. may, thus, be directly attributable to rapid development of education.

\subsection*{3.2.2 Value Added/Income Effect of Education}

Proportion or value added per unit of output manifests (i) degree
of round-aboutness in the methods of production being used in the economy, and (ii) efficiency of resource-use and productivity of factor-inputs. Round-about methods of production and factor productivities are directly related to the nature of technology which, however, vary inversely with each other. Increase in round-aboutness of production facilitates greater specialisation in production and rise in sectoral inter-dependence. The round-aboutness of production methods may lead to enhanced degree of sectoral inter-relateness, raising inter-industry demand. But an increase in intermediate-input requirements implies a corresponding decrease in value-added per unit of output. Such changes may then lead to a decline in productivity of the primary factors. If such changes lead to a fall in factor productivities, these changes will lower the growth performance of the economy as a whole, since development requires consistent and steady rise in factor productivities over time. In other words, inputoutput coefficients are required to decline for sustained development of the economy. It will, therefore, be interesting to evaluate income/value-added effect of education, on the one hand, and productivity effect, on the other.

Value-added and its components are shown below :
Value-Added
(Rs.in crores)


Education has contributed 2.96 per cent of total income of the economy. However, backward linkage effect of education on income accounts for only 0.21 per cent of total value-added in the economy, remaining income-effect of education being due to productivity.

Like gross-output of commodity sectors, value-added has grown very rapidly by 77.5 per cent in sixties. The growth of value-added has, however, decelerated to 11.75 per cent in seventies.

Income generated in commodity sectors' through their forward linkages with education has increased from 2.75 to 4 per cent of total income in 1979. The growth of income has, however, kept pace with the growth of output through-out the observed period. Consequently, the proportion of output accounted by income has remained almost stable around 64-66 per cent during these two decades of development, highlighting the maintenance of productivity levels through time for the economy as a whole, though inter-sectoral variations and changes therein are highly marked. Share of the tertiary sectors has increased from 20 in 1959 to 38 per cent of total income in 1989, while the share of agriculture has decreased from 52 in 1960 to 35 per cent in 1989. Contribution of education to income must have increased correspondingly due primarily to higher inputs of education into tertiary production, on the one hand, and upgradation of qualifications of manpower prompted by technological upgradation of production and educational development since the fifites, on the other.

Solution vectors of gross output of educational sectors have been determined with the help of the education sub-model of the system.

Imputed value of enrolments in educational institutions is Rs. 1289.84 crores in 1959 , representing economic value of potential stock of human capital.

Solution values of output vectors of education for 1969 and 1979 are reported below:

Educational Output (Rs. in Crores)
\begin{tabular}{|c|c|c|c|c|c|c|c|c|c|}
\hline Year/Sector & Prm & Md1 & Sec & \multicolumn{2}{|l|}{H.Sec - Clge Gn 1} & Clge Profnl & Tchrs ng Clge & Univ. & Total \\
\hline 1969:Actual & 562.15 & 390.74 & 404.23 & 883.57 & 40.96 & 19.83 & 1.89 & 19.59 & 2322. \\
\hline Estimated & 469.22 & 487.53 & 993.70 & 245.44 & 33.72 & 148.32 & 1.75 & 23.58 & 2403. \\
\hline 1979 : Actual & 699.68 & 830.08 & 267.38 & 199.66 & 176.14 & 492.42 & 12.48 & 232.23 & 2509. \\
\hline Estimated & 404.48 & 989.44 & 486.48 & 252.78 & 183.52 & 2196.30 & 57.54 & 132.89 & 2703 \\
\hline
\end{tabular}

Solution vectors of output of education closely approximate their actual values, MAPE statistics being only 0.0021 for \(1959,0.025607\) for 1969 and 0.00855 for 1979.
3.2.3 Productivity-Effect of Education

Productivity effect of education has universally been recognised as the promoter of growth and national development. Recognition of productivity effect of education, measured by differential earnings of manpower having education of different levels and types, has, in fact, led to the emergence of economics of education. Earning differentials, however, exclude post-retirement benefits, representing deferred payment for the contribution of human capital to output and productivity during the working life-span of manpower, resulting in under-estimation of the productivity-effect of education on growth.

In view. of the importance of productivity-effect of education, the effect has been determined separately for each sector. Productivity effect in commodity sectors has been decomposed into two components : productivity gains due to direct employment and productivity gains through forward linkages of commodity sectors with education. Estimates are reported below:


Like output and income effects, productivity-effect of education has grown rapidly through-out. An interesting aspect is, however, that the productivity-effect of education on income is much lower than the backward-linkage effect of education, highlighting the dimension of negligence of relatively more important component of education effect on growth than differential-earnings.

Besides these components of education effect on growth, education affects growth through residentiary linkages with the economy. Residentiary linkage (Prakash, 1986) relates to the consumption effect on income and output through the multiplier. Education promotes consumption of commodities in two ways : (a) income effect of education promotes consumption demand which, in turn activates multiplier process, and (b) education affects standards of living, specially through the entry of new goods into consumption baskets of the educated. Residentiary linkage effect of education may be determined with the help of income elasticities of consumption and income generated through education-effects on development. Income growth induced by education will equal the sum of (i) backward linkage effect of education on income; (ii) productivity effect of education on income; and (iii) income generated directly through employment and output in education sectors. Residentiary linkages-effect of education has not been determined in this exercise.

Education has accounted for 2.72 per cent of total income in 1969 which has increased to 4.2 per cent in 1979. More rapid growth of education than economy has thus raised the contribution of education from nearly 3 per cent in fifties to 4 per cent of income in seventies, rise of 1 percentage point.

\subsection*{3.2.4 Employment Effect}

Employment sub-model has been used to determine employment vector along with its sectoral distribution, qualificational patterns and sources of employment growth. The table below highlights the salient features of employment growth:

Employment (persons in lakhs)
\begin{tabular}{|c|c|c|c|c|c|}
\hline Year & Likage Effect with Education & \begin{tabular}{l}
--Commodity \\
Commodity \\
Production
\end{tabular} & sectorsTotal & Education Sectors & Grand Total \\
\hline 1959 & 2.24 & 1540.730 & 1542.97 & 19.63 & 1562.60 \\
\hline 1969 & 27.013 & 1555.072 & 1582.09 & 30.40 & 1612.49 \\
\hline 1979 & 150.063 & 2214.146 & 2364.21 & 37.58 & 2401.79 \\
\hline
\end{tabular}

A little more than one third of total population has been engaged in productive activities in 1959, leaving two thirds population as dependent. Ratio of dependent to economically active population is almost double. Educated accounted for only 21.87 lakh persons in employment, being 1.4 per cent of total employment. Of these, education itself'employed 19.63 lakh persons directly. Thus, 89.76 per cent of total educated manpower in the economy got absorbed in education itself.

First level education dominates educational profiles: of manpower, second level education accounting for only 3.37 per cent of total employment, reflecting general under-development of education during fifties when almost the entire stock of workforce had been brought
forward from pre-independence era. Under-developed state of education in fifities is also manifested by the fact that, on an average, Indians have had only 0.58 years of schooling in 1961. Average schooling of population has risen to 1.68 years in 1981. Workers have, however, had 0.79 years of schooling in 1961 which has grown to 4.77 years in 1981 (Prakash and Buragohain, 1992).

Educational qualifications of workforce in education sectors are much higher than of those employed in commodity sectors, matriculates and above accounting for 42.58 per cent, and graduates and above accounting for another 13.56 per cent of total employment in education. These qualificational patterns point towards (i) overall under-development of education sector, leading to the probable lowering of the desired qualifications to meet the shortages, and (ii) even greater degree of under-development of higher "education, and consequently, greater weightage having been assigned to school education in employment. Domination of employment by first level education also highlights the low technological and knowledge base of pr. duction in the Indian economy towards the end of the fifties. During seventies and eighties, the scenario must have changed considerably.

Total employment has increased very sluggishly in sixties. Employment growth has been greatly accelerated during seventies as is evident from the acceleration of growth of employment from 0.31 per cent in sixties to 4.1 per cent per annum in seventies. However, growth of direct employment in education has declerated from 4.47 per cent in sixties to 2.14 per cent in seventies, whereas growth of employment due to linkage effect of education has gone down from 28.3 to 18.7 per cent during the same period. Growth of direct employment
in commodity sectors has decined to 3.6 per cent per annum during the seventies. Interestingly, education has generated employment much more rapidly than commodity production.

Educational profiles of manpower have improved considerably from fifties to sixties and from sixties to seventies as is evident from the table given below :
(Persons in Lakhs
Year Educational Profiles of Total Employment
\begin{tabular}{|c|c|c|c|c|c|c|c|c|c|c|}
\hline & Iltrte & Ltrte without & Edn & Md 1 & H.Sec & Techr Trig for Gn 1 & Clge for Profn 1 & Total Clge & Univ. & Tc \\
\hline 1969 & \[
\begin{aligned}
& 980.43 \\
& (61.97)
\end{aligned}
\] & \[
\begin{aligned}
& 164.77 \\
& (10.41)
\end{aligned}
\] & \[
\begin{aligned}
& 229.28 \\
& (14.49)
\end{aligned}
\] & \[
\begin{gathered}
103.94 \\
(6.57)
\end{gathered}
\] & \[
\begin{array}{r}
56.60 \\
) \\
\hline
\end{array}
\] & \[
\begin{gathered}
0.07 \\
(0.0049)
\end{gathered}
\] & \[
\begin{gathered}
9.14 \\
(0.58)
\end{gathered}
\] & \[
\begin{gathered}
1.98 \\
(0.13)
\end{gathered}
\] & \[
\begin{gathered}
1.02 \\
(0.06)
\end{gathered}
\] & \[
\begin{gathered}
15 \varepsilon \\
16
\end{gathered}
\] \\
\hline 1979 & 884.35 & 688.92 & 320.74 & 242.02 & 123.91 & 4.77 & 78.19 & 20.76 & 0.54 & 236 \\
\hline & (37.41) & (29.14) & (13.31) & )(10.24) & ) 5.24 & ) (0.02) & (3.31) & (0.88) & (0.0023) & ) 1 C \\
\hline
\end{tabular}
(Figures in parantheses are percentages of total employment)

\subsection*{4.0 Solution of Generalised Dynamic Model-III}

Aggregation of sectors leads to the concealment of intra/inter sectoral variations, and (ii) underplaying of indirect effects. Results of empirical application of model-I to highly aggregated \(7 \times 7\) matrix of 1959 suffer from both these limitations. Then, model-I is static in nature which neglects investment, and hence, growth effect of education. Since dynamic linkage effects vary significantly from static linkage effects (Prakash, 1986), dyanmic version of generalised model-III has, therefore, been applied to 1969 and 1979 data. The results furnished by this model overcome limitations of aggreation of sectors and exogeneity of human and physical capital.
4.1 Dynamic Linkage Effect of Education on Output

Solution vectors of sectoral gross output are reported in statistical abstract. Gross output and its components for the economy as a whole are, however, reported below:

Output (Rs. in Crores)
\begin{tabular}{|c|c|c|c|}
\hline Year & \multicolumn{3}{|l|}{Commodity Sectors} \\
\hline \begin{tabular}{l}
Comodity \\
: Production
\end{tabular} & Linkage Total with Education & Education Sectors & n Grand Total \\
\hline 1969: Absolute 43662.71 Relative Shares 88.27 & \[
\begin{array}{rr}
3761.65 & 47424.36 \\
7.6 & 95.89
\end{array}
\] & \[
\begin{array}{r}
2043.07 \\
\quad 2.29
\end{array}
\] & \[
\begin{array}{r}
49467.43 \\
100.00
\end{array}
\] \\
\hline 1979:Absolute 131956.26 Relative Shares 83.15 & \[
\begin{array}{rr}
24099.56 & 156055.82 \\
15.19 & 98.33
\end{array}
\] & \[
\begin{array}{r}
2649.78 \\
1.67
\end{array}
\] & \[
\begin{array}{r}
1,58,705.60 \\
100.00
\end{array}
\] \\
\hline
\end{tabular}

Pattern of dynamic forward linkages of production sectors with education is considerably different from that of static inkages. Communications account for 16 per cent of overall linkage effect of education on output while mettalic-products and non-metalic mineral products each constitute 12.7 per cent of total output effect of education in 1979. Non-electrical machinery, agriculture and forestry, railway-transport service, petroleum products and other services contributed about 4 per'cent of total output due to backward linkage effect of education. In 1969, other transport equipment accounted for 19 per cent, while metalic products contributed about 11 per cent of output through forward linkages of commodity production with education. Steel and Other Services emerged next in ranking with a contribution of 7-8 per cent of overall output effect of education. These changes in pattern of linkage effects may be accounted by changes in levels and commodity composition of educational investment, and hence, changes in the commodity base of educational production. Differential growth of sub-sectors of education may also account for such changes. The emerging patterns of linkages highlight the shift of emphasis from teachers to buildings, laboratory equipment, travel, communications and services in educational production.

Gross output of commodity sectors has increased by 12.64 per cent from 1969 to 1979. Output due to direct commodity production has expanded at a slightly lower rate of 11.69 per cent, whereas output induced by forward linkages of commodity production with education has increased more rapidly by 20.41 per cent. Consequently, output induced by forward linkages of commodity production with education has increased from 7.6 in 1969 to 15.19 per cent of total output in 1979.

Value of direct educational output has increased by 2.63 per cent per annum whereas the economy has expanded at a rate of 12.64 per cent during the same period, though output induced by education both directly and indirectly has increased at a rate of 16.15 per cent. Thus, output induced by education has increased 1.3 times more rapidly than the output of the economy taken as a whole. Growth of output induced by forward linkages of commodity production with education has also grown much more rapidly than direct output of commodities. Education has, on the whole, accounted for 4.9 per cent of total output in 1969 which has risen to 16.9 per cent in 1979. Thus, the output-effect of education has increased three fold, raising contribution of education to growth in India with time both absolutely and relatively. An interesting feature, highlighted by these results, is that the static linkage effect of education on commodity production conceals a substantial proportion of dyanmic linkage effect on commodity output. Endogenisation of investment and growth facilitates the capturing of full magnitude of education effect on the economy. Output effect of education on individual sectors of commodity production, however, depends directly upon the scale effect, on the one hand, and commodity input intensity of education, on the other.

\subsection*{4.2 Dynamic Income Effect of Education}

Levels and patterns of output under conditions of dynamic growth are likely to reflect the levels and patterns of income. The following table supports this assertion :

Value-Added (Rs. in Crores)

(Figures in paretheses are percentages)
Income generated by commodity production has grown by 11.2 per cent per annum from 1969 to 1979. Income generated directly by production sectors has increased at a slightly lower rate of 10.3 per cent, whereas income induced by forward linkages with education has grown much more rapidly by 19.3 per cent per annum. Share of direct income has consequently deciined from 93 in 1969 to 86 per cent of total income in 1979, while income induced by linkage effect with education has risen correspondingly from 7 to 14 per cent, highlighting the rising weight of education in commodity production with development through time. Endogenisation of investment has thus revealed the true impact of education on the economy which has been partially concealed in static analysis. Share of income attributable to linkage effect with education is only 2.7 and 4.1 per cent of total income from commodity production in 1969 and 1979.

These results highlight certain intersting facets of material base of educational production in India :
(i) Input requirements of education to be satisfied by different
commodity sectors differ from sector to sector and from one/time period to another. Rank orders according to proportions of sectoral output required to satisfy inter-industry demand of education sector for material goods differ widely between sectors; (ii) patterns of backward linkages of education with the economy change sharply from one period to another. If education and economy change proportionately, rank correlation coefficient between proportions will be unity. But rank correlation is significantly lower than unity, value being only 0.672 , implying significant changes in educational and commodity production technology having occurred through time. The finding suggests that (i) even if the technology of commodity production remains invariant, technology of production of social sectors, particularly education tends to change; (ii) if technology of commodity production changes, educational technology changes even more rapidly, technology of social sectors, particularly education, is highly flexible. High flexibility of response from education to changes in the technology of commodity production and operational constraints of the system facilitates educational technology to change relatively more rapidly than commodity production technology (Prakash, 1976, 1977), and (iii) printing and allied activities, paper and paper products, electricity, other transport services, machine tools, and electrical machinery and appliances, in that order, in 1969 and printing and allied activities, paper and paper products, railway and other transport services, chemicals and. chemical products, electrical appliances and transport equipment in 1979 depend more on forward linkages with education than other sectors.

If, however, real resource inputs decline even while education expands quantitatively or resource inputs grow less than proprotionately, backward linkage effect of education on output will be weak. Resource inputs will directly affect the educational technology in use, leading to the dilution of stock-inputs, and hence, the quality of infrastructural facilities like buildings and equipment. Linkage effect therefore, depends partly upon resource allocation and partly upon the flexibility of educational technology.

\subsection*{4.3 Productivity Effect of Education}

As discussed earlier, productivity effect of education has been considered as the most important effect of education on growth. But the productivity effect, like output and income effects, is likely to differ considerably for static and dynamic models. Hence, dynamic productivity effect has also been analysed separately :
(Rs. in Crores)
\begin{tabular}{|c|c|c|c|c|c|c|}
\hline \multirow[t]{2}{*}{Year} & \multicolumn{2}{|l|}{------Commodity} & \multirow[b]{2}{*}{Total} & \multirow[t]{2}{*}{\begin{tabular}{l}
----Educat \\
Education Sector
\end{tabular}} & \multicolumn{2}{|l|}{Sectors-----} \\
\hline & Commodity Production & Forward Linkages with Education & & & Grand Total & Growth Rate \\
\hline 1969 & \[
\begin{array}{r}
30,342.24 \\
(93.63)
\end{array}
\] & \[
\begin{array}{r}
1861.50 \\
(5.74)
\end{array}
\] & \[
\begin{gathered}
32,203.74 \\
(99.38)
\end{gathered}
\] & \[
\begin{array}{r}
200.06 \\
) \quad 0.621
\end{array}
\] & \[
\begin{gathered}
32403.8 \\
(100)
\end{gathered}
\] & \\
\hline 1979 & \[
\begin{array}{r}
201781.09 \\
(94.95)
\end{array}
\] & \[
\begin{array}{r}
10421.55 \\
(4.90)
\end{array}
\] & \[
\begin{array}{r}
212,203.64 \\
(99.85)
\end{array}
\] & \[
\begin{array}{r}
301.25 \\
) \quad(0.15)
\end{array}
\] & \[
\begin{gathered}
212503.89 \\
(100)
\end{gathered}
\] & 6.56 \\
\hline
\end{tabular}
(Figures in parentheses are percentages)
Overall productivity effect has increased rapidly at a rate of 20.80 per cent per annum. But the linkage effect with education on productivity has increased at a slightly lower rate of about 19 per cent, while the direct productivity has risen by 20.9 per cent. Share of forward linkage effect on overall productivity has consequently declined nominally from 5.8 to 4.9 per cent of the total productivity gains. Productivity effect of dynamic growth is, however, lower than that for state model.

\subsection*{4.4 Employment Effect}

Endogenisation of investment and growth tends to after income, output and productivity effects of education. Hence, employment effect of education may be also different. Employment effect of dynamic growth of the economy is tabulated below :
(Persons in Lakhs)
\begin{tabular}{|c|c|c|c|c|c|c|}
\hline \multirow[t]{2}{*}{Year} & \multicolumn{6}{|l|}{----------mmodity Sectors} \\
\hline & Commodity Production & Forward Linkages with Education & Total & Education Sector & Grand Total & Overall Growth \\
\hline 1969 & \[
\begin{gathered}
1331.89 \\
(95.28)
\end{gathered}
\] & \[
\begin{aligned}
& 65.99 \\
& (4.72)
\end{aligned}
\] & \[
\begin{aligned}
& 1397.88 \\
& (100)
\end{aligned}
\] & 27.62 & 1425.5 & \\
\hline 1979 & \[
\begin{array}{r}
1746.71 \\
(18.51)
\end{array}
\] & \[
\begin{aligned}
& 249.41 \\
& (12.49)
\end{aligned}
\] & \[
\begin{aligned}
& 1996.12 \\
& (100)^{2}
\end{aligned}
\] & 40.37 & 2036.49 & 3.63 \\
\hline
\end{tabular}

Overall employment in'production sectors of the economy has expaned at a rate of 3.63 per cent per annum which is much lower than output growth, implying an extremely rapid growth of productivity which may be attributed to technological upgradation of production base and rising knowledge endowment of manpower. Forward linkage effect on employment has grown more rapidly by 14 per cent. Employment generated by direct commodity production has, however, increased at a relatively sluggish rate of 2.75 per cent. Consequently, employment in production sectors accounted by forward linkages with education has risen from 4.7 in 1969 to 12.5 per cent of total employment in 1979. Employment growth in dynamic model is relatively slower than that in static case, implying that productivity gains of growth are partially concealed by static model.

Conclusions :
Empirical applications of input-out models show that neglect of indirect effects of education on output, income, productivity and
employment has led to considerable under-estimation of economic value of education. This has, however, been in-built in the narrowness of the conceptual basis of conventional analysis. Growth of output, income, productivity and employment induced by backward linkage effects of education on commodity production are much larger than the productivity gains. Then, the dynamic growth gains are larger than what static analysis can reveal. Results of the study, therefore, highlight the inadequacy of conventional accounting of economic effects of education, on the one hand, and limitations of the conceptual frame and theoretical base of educational economics. The concept of economic value of education is too narrow to encompass indirect and ultimate economic effects of education in totality. Conceptual base of human capital requires broadering where dyanamic input-output modelling will serve the methodological needs.

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Table 1
STATIC KODEL-1
OUTPUT AND INCOME (RS. IN LAKHS)
1959
\begin{tabular}{|c|c|c|c|c|c|c|c|c|}
\hline \multirow[b]{4}{*}{Production Sectors} & \multirow[b]{3}{*}{\begin{tabular}{l}
Comadity \\
Production
\end{tabular}} & & \multirow{4}{*}{Total} & \multirow[b]{4}{*}{Value
Added} & \multicolumn{3}{|c|}{Percentape Shares} & 1 \\
\hline & & Linkage & & & 1 Comodity & Linkage & & 1 \\
\hline & & With & & & 1 Production & nith & Total & 1 \\
\hline & & Education & & & 1 & \multicolumn{2}{|l|}{Education} & 1 \\
\hline \multirow[t]{2}{*}{Aopriculture} & 881726.2 & 342.4 & 882862.5 & 592269.6 & I 52.43393 & 9.028361 & 52.45428 & 1 \\
\hline & & & & & 1 & & & 1 \\
\hline \multirow[t]{2}{*}{Mining} & 16227.4 & 75.25 & 16302.63 & 13486.83 & 10.965887 & 0.084474 & 0.969481 & 1 \\
\hline & & & & & 1 & & & 1 \\
\hline \multirow[t]{2}{*}{Domestic Production} & 264856.6 & 583.92 & 265360.5 & 107916.4 & 115.75043 & 0.029966 & 15.78039 & I \\
\hline & & & & & 1 & & & 1 \\
\hline \multirow[t]{2}{*}{Industrial Consuapt} & 65355.64 & 431.2 & 65786.83 & 29239.04 & 13.886554 & 8.025642 & 3.912196 & I \\
\hline & & & & & 1 & & & 1 \\
\hline \multirow[t]{2}{*}{Heavy Investaent - '} & 71785.45 & 639.63 & 72425.88 & . 33617.37 & 14.268920 & 6.038037 & 4.316857 & 1 \\
\hline & & & & & 1 & & & 1 \\
\hline \multirow[t]{2}{*}{Mechinery} & 41999.96 & 74.17 & 42874.13 & 17867.42 & 12.497643 & 0.044110 & 2.582854 & I \\
\hline & & & & & & & & I \\
\hline \multirow[t]{2}{*}{Services} & 335993.1 & 1578.47 & 337571.5 & 286169.8 & 119.98876 & 0.893868 & 24.07462 & I \\
\hline & & & & & & & & I \\
\hline \multirow[t]{2}{*}{Total} & 1677938.35 & 3645,84 & 1681583.17 & 1088486. & 199.78325 & B.216762 & 180 & 1 \\
\hline & & & & & 1 & & & I \\
\hline
\end{tabular}

Table 2
static model-1
OUTPUT AND IMCOME (RG. IN LAKHS)
1969
\begin{tabular}{|c|c|c|c|c|c|}
\hline Connodity Sectors ; & \begin{tabular}{l}
Comodity \\
Production
\end{tabular} & \begin{tabular}{l}
Linkag̣e \\
With \\
Education
\end{tabular} & TOTAL & \begin{tabular}{l}
Value \\
Added
\end{tabular} & 1
1
1 \\
\hline 1 Agriculture & 1325927. & 1736.573 & 1327664. & 996798.3 & 1 \\
\hline 2 Forestry \& logging & 422572.8 & 1875.653: & 424448.4 & 319521.4 & 1 \\
\hline 3 Hining & 65824.76 & 2518.324 & 68343.88 & 59863. 22 & 1 \\
\hline 4 Sugar & 91786.87 & 388.6807 & 92895.55 & 47014.32 & 1 \\
\hline 5 Food products excluding sugar & 286288.5 & 2744.594 & 299025.1 & 127369.7 & 1 \\
\hline 6 Textiles & 389181.5 & 2729.661 & 391911.2 & 201884.8 & 1 \\
\hline 7. Mood and mood products & 63117.99 & 1884.922 & 64922.91 & 47378.84 & 1 \\
\hline 8 Paper \& paper product & 34554.68 & 18314.61 & 44869.30 & 25452.48 & 1. \\
\hline ¢ Printing, publishing and allied industry & 32197.58 & 294.5036 & 32492.80 & 19480.49 & 1 \\
\hline 8 Leather t leather products & 25495.82 & 51.49771 & 25547.31 & 11332.96 & 1 \\
\hline 1 Plastic rubber products & 13976.02 & 3548.294 & 47518.32 & 15841.54 & 1 \\
\hline 2 Petroleun products & 37190.48 & 1284.931 & 38475.33 & . 28476.39 & 1 \\
\hline 3 Chenicals and cheoical products & 265874.9 & 4212.457 & 270487.4 & 176934.8 & 1 \\
\hline 4 Cenent & 9631.271 & 158.1135 & 9789.384 & 1738.717 & 1 \\
\hline 5 Non-aetallic aineral products & 99178.28 & 932.0974 & 180118.2 & 76246.32 & J \\
\hline 6 Iron 4 steel industries \({ }^{\text {d foundries }}\) & 83949.99 & 11359.18 & 95399.17 & 38512.28 & 1 \\
\hline 7 Other basic aetal industry & 64169.17 & 5512.872 & 69681.24 & 56712.38 & 1 \\
\hline 8 hetal products except asch. \& tpt, equip. & 55425.99 & 16684.34 & 72110.34 & 21187.48 & 1 \\
\hline \% Non-Electrical Machinery & 44969.51 & 1262.686 & 46172.28 & 15126.84 & 1 \\
\hline Blectrical, electronic, ash.\& equip. & 37161.98 & 1124.675 & 38286.66 & 15171.93 & 1 \\
\hline 1 Railmay tpt. equip. & 16173.94 & 636.1365 & 16818.89 & 7868.455 & 1 \\
\hline 2 Dther tpt. equip. & 53682.66 & 39273.44 & 92956.18 & 34322.42 & 1 \\
\hline 3 Hiscellaneous amat. industries & 33873.95 & 5462.445 & 39276.39 & 29671.43 & 1 \\
\hline 1 Construction & 393449.5 & 5858.496 & 398588.1 & 219569.8 & 1 \\
\hline 5 Electricity & 51831. 64 & 3146.250 & 57977.89 & 33951.93 & 1 \\
\hline 6 6as and mater supply & 10683.37 & 3181.385 & 13784.68 & 10414.27 & 1 \\
\hline 7 Railmay trans . sery. & 184878.9 & 8428.435 & 113397.4 & 77281.61 & 1 \\
\hline 8 Other transport ser. & 183943.7 & 3485.629 & 187349.3 & 107642.7 & 1 \\
\hline 9 Storage \& warehousing & 3239.666 & 1598.242 & 4829.919 & 3858.581 & I \\
\hline 8 Comunication & 20669.66 & 8914.885 & 29583.74 & 25873.65 & 1 \\
\hline 1 Trade & 289878.7 & 8651.996 & 286729.8 & 234781.5 & 1 \\
\hline 2 Hotels \& restaurants & 42930.59 & 41.15251 & 42071.74 & 27457.18 & 1 \\
\hline 3 Banking & 40513.27 & 853.3995 & 41366.67 & 32856.39 & 1 \\
\hline 4 Insurance & 17682.99 & 1384.025 & 18987.02 & 17602.77 & 1 \\
\hline 5 Omnership of dwellings & 87261 & 0 & 87261 & 43128.98 & 1 \\
\hline 6 Medical \& health & 71151 & 3311.852 & 74462.85 & 66579.81 & 1 \\
\hline 7 Other services & 126209.7 & 3549.364 & 129750.1 & . 116191.6 & 1 \\
\hline TOTAL & 4938727. & 165137.1 & 5183864. & 3373687. & 1 \\
\hline
\end{tabular}

Table 3
static model-1
OUTPUT AND INCOME (RS. IN LAKHS)
1979
\begin{tabular}{|c|c|c|c|c|c|}
\hline Comeodity Sectors; & \begin{tabular}{l}
Comodity \\
Production
\end{tabular} & \begin{tabular}{l}
Linkage \\
Hith \\
Education
\end{tabular} & Total & \begin{tabular}{l}
Value \\
Added
\end{tabular} & 1
1
1
1 \\
\hline 1 Agriculture & 5162726. & 14934.38 & 5177668. & 4491457. & I \\
\hline 2 Foresty and logging & 651222.8 & 13855.16 & 665888.8 & 633021.3 & 1 \\
\hline 3 Hining t Buarrying & 126497.9 & 181.6111 & 126679.5 & 33362.25 & 1 \\
\hline 4 Sugar & 631218.5 & 1356.246 & 632574.7 & 178213.5 & 1 \\
\hline 5 Food product Excl. sugar. & 976258.2 & 4049.882 & 989307.3 & 289786.9 & 1 \\
\hline 6 Textile Product & 169283.7 & 8288.972 & 177492.7 & 114248.9 & 1 \\
\hline 7 Hood and wood Products & 185796.3 & 3945.565 & 189741.8 & 59775.34 & 1 \\
\hline 8 paper. and paper pro. & 78524.62 & 1842.596 & 71567.21 & 38496.46 & 1 \\
\hline 9 Print.publ.and allied act. & 89242.37 & 66.35149 & 89388.72 & 35879.41 & 1 \\
\hline 18 Leather leather pro. & 93322.85 & 2958.573 & 96279.43 & 23292.28 & I \\
\hline 11 Plastic, Rubber Product & 176311.2 & 5941.885 & 182253.1 & 59153.89 & 1 \\
\hline 12 Petolié pro. & 518477.5 & 23697.48 & 534175.0 & 118341.7 & I \\
\hline 13 Chenicals and chenicals pro, & 49648.91 & 4673.267 & 54314.18 & 19555.58 & 1 \\
\hline 14 Ceaent & 239842.1 & 20174.93 & 268017.1 & 189564.3 & 1 \\
\hline 15 Mon-setallic sineral products & 458274.2 & 41592.98 & 499867.1 & 188888.9 & 1 \\
\hline 16 irontsteel industries & 180148.1 & 7788.172 & 187928.2 & 137113.6 & 1 \\
\hline 17 0ther basic metal & 119611.7 & 7348.885 & 126951.8 & 33704,29 & 1 \\
\hline 18 netal.pro. except sach. & 144591.3 & 25784.89 & 178374.4 & 36368.13 & 1 \\
\hline 19 non- elect. sach. & 111033.2 & 9394.984 & 128428.1 & 2570. 58 & I \\
\hline 28 electl, elec asch, aschequp. & 54229.97 & 2654.466 & 54886. 44 & 39917.53 & 1 \\
\hline 21 railmay tpt.equip & 158121.2 & 2380.308 & 152581.5 & 23536.93 & 1 \\
\hline 22 other tpt, equip & 148978.2 & 19942.02 & 160928.2 & 22469.14 & 1 \\
\hline 23 nisc. manf indust. & 192728.5 & 21967.57 & 214696.1 & 2662.232 & 1 \\
\hline 24 construction & 249692,6 & 13682.85 & 263375.4 & 123617.8 & 1 \\
\hline 25 electricity & 41661.95 & 1133.803 & 42795.76 & 21615.49 & 1 \\
\hline 26 gas 4 water supply & 283887.9 & 9856.181 & 213744.1 & 83180.43 & 1 \\
\hline 27 rly. tpt. services & 681445.1 & 19466.27 & 788911.4 & 388927.6 & 1 \\
\hline 28 other tpt servicas & 56896.47 & 629.6249 & 57526.18 & 54284.23 & 1 \\
\hline 29 storage \% warehousing & 79192.98 & 12621.91 & 91814.89 & 81804.37 & 1 \\
\hline 38 Communication & 1428565. & 52787.89 & 1481352. & 959614.9 & 1 \\
\hline 31 trade & 395850.3 & 3648.851 & 389499.4 & 221047.2 & 1 \\
\hline 32 hotelst restrurents & 215083.3 & 55387.63 & 270391.8 & 284744.8 & 1 \\
\hline 33 banking & 255655.1 & 1953.325 & 257688.4 & 253710.1 & 1 \\
\hline 34 insurance & 341569.8 & 8. 824957 & 341569.8 & 313565.8 & I \\
\hline 35 aedicalt health & 319761.2 & 1049.407 & 329818.6 & 257628.6 & 1 \\
\hline 36 other services & 284683.2 & 1861.899 & 286545.1 & 71455.12 & 1 \\
\hline 37 public adsinistration & 383162.2 & 230339.8 & 613581.3 & 549782.9 & 1 \\
\hline & & & & & 1 \\
\hline TOTAL & 15371166 & 648345.8 & 16819452 & 10245629 & 1 \\
\hline
\end{tabular}

Table 4
GENERALISED DYMAMIC MODEL-1II
OUTPUT AND INCOHE (RS. IN LAKHS)
1969


Table 5
GENERALISED DYKAHIC MODEL-11!
gUIPUT AND INCOME (RS. IN LAKHS)
1979
\begin{tabular}{|c|c|c|c|c|c|}
\hline tion Sectors & \begin{tabular}{l}
Comodity \\
Production
\end{tabular} & \begin{tabular}{l}
Linkage \\
With \\
Educatin
\end{tabular} & Total & Value Added & 1
1
1
1 \\
\hline 1 ture & 1518342. & 48797.99 & 1551148. & 1318603. & I \\
\hline \multirow[t]{3}{*}{ry \& logging} & 678721,6 & 85939.43 & 764651.1 & 727793.5 & 1 \\
\hline & 37519.53 & 668.8215 & 38178.35 & 13872.46 & 1 \\
\hline & 119360.9 & 5929.325 & 125298.2 & 47826.78 & 1 \\
\hline oducts excluding sugar & 326863.6 & 24852.39 & 358916. & -115326.0 & 1 \\
\hline 5 & 359619.1 & 29541.38 & 389168.4 & 258495.6 & 1 \\
\hline d mood products & 127966.7 & 28883.77 & 148778.5 & 81033.86 & 1 \\
\hline paper product & 21516.99 & 6859.806 & 28376.88 & 12456.33 & 1 \\
\hline 1 ,publishing and allied i & in23104.57 & 3829.158 & 26929.73 & 10818.91 & 1 \\
\hline \& leather products & 156879.2 & 32019.21 & 188098.4 & 68980.87 & 1 \\
\hline ( rubber products & 171919.4 & 38814.11 & 210733.5 & 68397.78 & 1 \\
\hline - produrts & 462981.6 & 118964.0 & 581945.6 & 186684.6 & 1 \\
\hline \multirow[t]{2}{*}{5 and chenical products} & 127758.5 & 11358.63 & 139189.1 & 58885.63 & I \\
\hline & 145495.8 & 52747.89 & 198242.9 & 144528.1 & 1 \\
\hline llic aineral products & 148616. & 318235.2 & 1366852. & 494616.5 & 1 \\
\hline \multicolumn{2}{|l|}{teel industries ffoundriest06117.7} & 189721.8 & 516138.8 & 376578.2 & 1 \\
\hline sic aetal industry & '285659.7 & 56313.64 & 261972.8 & 85546.93 & 1 \\
\hline \multicolumn{2}{|l|}{sducts except mach. 1 tpt.867184.5} & 385768.3 & 1172952. & 376923.7 & 1 \\
\hline rical Machinery & 568066.8 & 164297.8 & 738364.6 & 234699.7 & 1 \\
\hline \multicolumn{2}{|l|}{13, electronic, mach. E equ71369.36} & 12768.52 & 81129.88 & 57789.47 & 1 \\
\hline pt. equip. & 75243.86 & 38595.76 & 105839.5 & 44615.97 & 1 \\
\hline - equip. & 67675.38 & 28956.93 & 95732.32 & 49341.24 & 1 \\
\hline eous mant, industries & 139965.1 & 49124.61 & 188989.7 & 100561.6 & 1. \\
\hline tion & 1336821. & 82777.48 & 1419599. & 666382.6 & 1 \\
\hline ty & 31379.83 & 6978.988 & 38358.81 & 19374.45 & 1 \\
\hline iter sappiy & 364868.4 & 58297.05 & 415075.5 & 233675.2 & 1 \\
\hline 'ans . sery. & 588703.8 & 125189.8 & 625892.8 & 339352.8 & I \\
\hline sport ser. & 155201.9 & 4538.611 & 159732.5 & 159738.8 & 1 \\
\hline warehousing & 51384.99 & 18755.34 & 70148.33 & 61881.82 & 1 \\
\hline \multirow[t]{2}{*}{ion} & 1920116. & 387738.4 & 2387846. & 1495014. & 1 \\
\hline & 214359.2 & 5882.943 & 228162.1 & 157242.2 & 1 \\
\hline \multirow[t]{3}{*}{2staurants} & 224551.1 & 42722.45 & 267273.6 & 292383.5 & 1 \\
\hline & 145839.7 & 18438.58 & 155478.3 & 153117.6 & 1 \\
\hline & 554.5238 & ใ. 167882 & 554.6917 & 589.2145 & 1 \\
\hline if dwellings & 92182.38 & 1127.888 & 93318.18 & 74938.89 & 1 \\
\hline ealth & 74982.89 & 15136.92 & 98839.82 & 48134.45 & I \\
\hline \multirow[t]{2}{*}{CP5} & 366133.4 & 111466.8 & 477609.3 & 427934.3 & 1 \\
\hline & 13195626 & 2499956. & 15685582 & 892859. & 1 \\
\hline
\end{tabular}

\title{
INDUSTRIAL EFFECTS OF THE EUROPEAN COMMUNITY INTEGRATION
}

\author{
Costas Christou and Douglas Nyhus
}

\begin{abstract}
This paper examines the potential effects of the European Community (EC) integration. It develops a number of assumptions representing the EC directives, and introduces them in the Inforum system of models, which links together interindustry dynamic macro-economic models of ten countries. Those assumptions include the deregulation of financial services, abolition of border controls, increased competition, economies of scale and opening up of government procurement. According to the system results, the European economies will experience higher economic growth and per capita income with lower prices and higher labor productivity. It is expected that the rest of the world economies will not be affected significantly by the integration. Finally, the integration process will generate diverse results across sectors in different countries.
\end{abstract}

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\section*{I. Introduction}

In the beginning of 1993, the European single market will materialize. It will bring to fruition years of enthusiastic work inspired by an ambitious vision of a unified Europe. The estimation of the potential effects of the integration has been the main area of research for many economists of both sides of the Atlantic [Cecchini (1988), Commission of the European Communities (1988) and (1990), Catinat and Italianer (1988) for the micro aspects of the integration and Economic Policy (1989) and Coffey (1990) for the major macro and growth related issues]. Most of the 1992 integration of Europe studies deal mainly with the aggregate macroeconomic effects of the integration, without paying a lot of attention to the industrial - or sectoral - impacts of it.

The objective of this paper is to examine the potential effects with an internationally linked system of models, namely the Inforum system. It includes the interindustry dynamic macro-economic models of five European countries (Belgium, France, Germany, Italy and Spain) and models of Canada, Japan, Mexico, South Korea and the United States; the models are annual and sectorally linked through merchandise trade and prices. Information regarding trade flows and prices is exchanged between each of the sectors of the national models. The expression "interindustry macro-economic" means that the models deal with all of the usual concerns of macroeconomics -- but build up macro totals from industry detail. The basic structure is more or less common to all of the models and is described in Nyhus (1988) and (1991). Both national models and the linking mechanisms are described in Economic Systems Research (1991).

Two scenarios were developed. One represents the current situation, that is Europe with borders. For the other, a number of assumptions representing the European Community (EC) directives were quantified and entered into the models, to produce the Europe without borders scenario. They represent major supply shocks in the form of deregulation of financial services, abolition of border controls, opening up of government procurement, increased competition and economies of scale. The first three were implemented in 1993 while the latter two in 1995, as the adjustment process is expected to be longer. Since the assumptions for the Europe 1992 program pertain to only four of the twelve European Community countries, the results are probably biased downwards. The lack of repercussions deriving from both the income and the price side of the other European economies limits the favorable results of the integration.

According to the system results, the integration process will boost the European economies but produce slightly negative results for the other economies considered. Because of the 1992 program, output in the year 2000 is expected to be \(9.74 \%\) higher in Belgium, \(5.53 \%\) higher in France, \(6.14 \%\) higher in Germany and \(2.94 \%\) higher in Italy than it would
be without the program. The corresponding increases in exports will be \(9.74 \%, 10.59 \%\), \(7.31 \%\) and \(5.65 \%\) while employment is expected to increase by \(0.35 \%\) in Belgium, \(0.38 \%\) in France and \(0.45 \%\) in Germany. In Italy a significant number of workers will be displaced by higher rates of productivity growth; and, as a result, employment will be lower by \(2.20 \%\). For the Republic of Korea and the United States, the results on output growth are negligible (reductions of \(0.49 \%\) and \(0.16 \%\) respectively by 2000 ). Export reductions are \(2.11 \%\) and \(1.04 \%\), while the effects on employment are again very small; reductions of \(0.32 \%\) and \(0.05 \%\) respectively.

The rest of the paper is organized in the following manner. Section II discusses each of the assumptions that were made, together with the methodology followed for their implementation. Section III continues with the results of the simulations and a comparison of them with the ones obtained by the Cecchini study. Finally, section IV summarizes and concludes.

\section*{II. Assumptions}

The assumptions of the Europe without borders scenario appear in Figure 1. Those can be regarded as a sequence of major supply-side shocks that are expected to have both micro and macroeconomic effects on the economies of the member countries as well as on the rest of the world.

Figure 1 Assumptions for the single European market program.
- Deregulation of financial services
- Removal of border related controls
- Increased competition in
(a) wholesale and retail trade
(b) industrial sectors and services
- Exploitation of the economies of scale
- Opening up of government procurement

At the micro level, after the removal of barriers and regulations, the drop in consumer prices together with a larger choice of products of better quality will result in substantial gains for the consumers. In other words, there will be welfare gains as measured by the consumer surplus. For the producer, there might be short-run losses which will be outweighed by the creation of long-run profits. Because of the immediate elimination of protectionism and the monopolies that currently exist, profits are expected to drop. Increased competition, though, will induce firms to adjust their behavior and exploit
economies of scale in production, reduce X -inefficiencies and internalize externalities in learning and innovation. Those will provide the foundations for potential long-term profits.

At the macro level, the immediate outcomes of the internal market program will be the reduction in production costs and significant gains in productivity. Prices will drop and increase the competitiveness of the EC economies and thus the purchasing power of their residents. That rise will in turn stimulate final demand -- both domestic and foreign -- giving companies the opportunity to exploit resources better and increase their level of activity and production. Inflation and unemployment will then be reduced; new perspectives for growth will improve the confidence of businessmen and consumers in those economies.

The rest of this section examines in detail the assumptions about the European integration, which appear in Figure 1. In the course of quantifying them, information was drawn from a number of existing studies and especially from the Cecchini report (1988) and the study by Catinat and Italianer (1988). They both contain specific estimates of the expected shocks across countries and sectors.

\section*{(i) Deregulation of financial services}

It is well known that vitality of an economy requires a financial sector with the smallest possible imperfections. In most of the European Community countries, though, government regulations, standards, and controls have restricted market entry in many financial sectors and implicitly abolished free competition. As a result, there are big differences in the prices of standard financial products across the EC. Price differentials between the cheapest and the most expensive provider range from \(46 \%\) for obtaining travellers cheques to \(254 \%\) for insurance against commercial fire and theft [Cecchini (1988)].

The Commission directives for the deregulation of financial services involve a twophase plan, the first stage of which was implemented in 1987. The main idea of the plan is the elimination of controls on capital movements. The potential benefits affect both the micro and the macro side of the economy. On the micro side, because of increased competition there will be efficiency gains which will lead to a reduction in the price of financial services and to an increase in labor productivity while on the macro side the elimination of controls and regulations will make it easier for both the country and the EC policymakers to coordinate their policies.

The Cecchini report estimated that the reductions in the price of financial services could be as high as 11 percent for Belgium, 12 percent for France, 10 percent for Germany, and 14 percent for Italy. It is expected that those savings will be reflected in lower valueadded components for the financial sectors. Thus, the value of their output (in current prices) will be lower. The above reductions were introduced into the European models in
the form of savings in total labor compensation and profits of the above sectors.

\section*{(ii) Removal of border-related controls}

The existence of border controls and administrative formalities makes businesses suffer massive customs-related paperwork which creates long delays in the dispatch of goods to other Community markets. Small and middle-sized companies are hurt the most. According to Cecchini, customs costs per consignment can be up to 30 to 45 percent higher for companies with under 250 employees than for larger companies. Thus, the impacts of the removal of border controls will be uneven across countries. An additional unevenness will arise because of the different geographical location of the EC countries.

A number of measures aiming at reducing border checks have already been taken by the European governments, with the objective of having all border controls eliminated and administrative formalities reduced by the end of 1992. The potential effects of those measures will be two-fold. First, government employment will be cut down as a result of the elimination of customs officers. In order to implement that effect, public employment in our models was reduced by 0.41 percent for Belgium, 0.21 percent for France, and 0.06 percent for Germany and Italy [Catinat and Italianer (1988)]. Second, the price of the intraCommunity trade will be reduced, since the extra costs of delays and administrative formalities are paid either directly or indirectly by importing firms. Catinat and Italianer have estimated the share of the cost of administrative formalities borne by the firms in the value of the bilateral trade flows. Those shares are based on estimates of the administrative costs per consignment for the importers and the exporters of each of the countries analyzed and for different products. Figure 2 presents the matrix of the above shares.
Figure 2 Share of the cost of the administrative formalities borne by the EC firms in the value of bilateral trade flows - all products taken together.
\begin{tabular}{lcccccc}
\(\quad\)\begin{tabular}{l}
\(\quad\) Importer \\
Exporter
\end{tabular} & Belgium & Germany & France & Italy & Netherlands & UK \\
Belgium & & & & & & \\
Germany &. & 0.84 & 1.21 & 1.42 & 0.94 & 0.84 \\
France & 1.45 &. & 2.10 & 2.17 & 1.82 & 1.67 \\
Italy & 1.64 & 1.72 &. & 2.25 & 1.84 & 1.72 \\
Netherlands & 1.76 & 2.25 & 2.30 &. & 1.95 & 1.83 \\
UK & 1.05 & 1.22 & 1.40 & 1.59 &. & 1.27 \\
& 1.87 & 1.20 & 1.55 & 1.91 & 1.33 &.
\end{tabular}

Source: Catinat and Italianer (1988).

The rows represent the exporting countries and the columns the importing. For modeling purposes, it was assumed that the elimination of customs related controls would result in a reduction of the bilateral export prices. In order to come up with the appropriate price reductions for each country's exports, the structure of its trade was taken into consideration. For a given country, let \(s_{i j}\) be the share of sector i's exports to country \(j\) in the total value of exports to country \(j\); and, \(\mathrm{RF}_{\mathrm{j}}\) the export price reduction factor for exports to country j (presented in Figure 2). Then, the weighted-average reduction factors (WARF) are calculated according to the following formula:
\[
\mathrm{WARF}_{\mathrm{i}}=\sum_{\mathrm{j}}\left(\mathrm{~s}_{\mathrm{ij}} * \mathrm{RF}_{\mathrm{j}}\right)
\]
(By definition, \(\sum_{i} s_{i j}=1\) for all \(j\).) That procedure gave vectors with the WARF's for the exporting sectors of each of the countries considered. Finally, multiplicative fixes were applied in order to reduce sectoral export prices by the WARF's.

\section*{(iii) Increased competition}

A larger internal market will boost competition and reduce monopoly power and rents as well as X -inefficiencies, that is, management inefficiencies. The drop in the unit costs and profit margins will result in lower producer and consumer prices. Those effects are expected to be different across sectors.

\section*{(a) Wholesale and retail trade sectors}

After the removal of the trade restrictions, it is expected that the average size of the wholesale and retail trade companies will increase -- by means of the establishment of big chains of stores. That will result in the reduction or even the elimination of price discrimination among the EC countries.

The reduction in trade margins will lead to increases in labor productivity in trade and consequently to lower consumer prices. The whole adjustment process requires that companies make all necessary changes in order to bear increased competition, and thus it is expected to be gradual.

That expectation is reflected in the way this potential effect was implemented. It was assumed that labor productivity in both the wholesale and the retail trade sectors will increase by 8 percent by 1995, above that of the Europe with borders scenario, and then steadily move up to a 15 percent increase by 2000 and remain the same until 2010. All of those increases are in addition to the trend increases assumed in the Europe with borders scenario.

\section*{(b) Industrial sectors and Services}

The elimination of X -inefficiencies together with improvements in management, by
reorganizing managerial teams, will result in reductions in the unit costs of production. Those estimates, as they appear in Figure 3, were derived by using the differences in prices now observed between member states as an indicator of future competitive pressures (for details see Catinat and Italianer). It was assumed that the adjustment of the firms will be gradual, starting in 1995 and the assumed cost reductions were implemented as labor productivity increases.

Figure 3 Decrease in unit costs of production (in percent), as a result of increased competition: all countries.
\begin{tabular}{ccccc} 
& \begin{tabular}{c} 
Intermediate \\
goods
\end{tabular} & \begin{tabular}{c} 
Equipment \\
goods
\end{tabular} & \begin{tabular}{c} 
Consumption \\
goods
\end{tabular} & \begin{tabular}{c} 
Services
\end{tabular} \\
(except trade \& government)
\end{tabular}

Source: Catinat and Italianer (1988) and authors' estimates.

\section*{(iv) Exploitation of the economies of scale}

Increased competition will induce firms to organize their production processes more efficiently and exploit economies of scale. Production costs will drop and labor productivity will increase. Additional production possibilities are expected to lead to an increase in the market share of the EC industries with the rest of the world.

For modeling purposes, it was assumed that the average size of the establishments will converge towards the minimum efficient technical scale (which differs across industries). Estimates of those appear in Catinat and Italianer. The reductions in the unit costs of production were assumed to be identical across all countries due to lack of country specific information on cost savings. Cost reductions as they appear in Figure 4 were translated into . labor productivity increases. Again, the adjustment process is expected to be gradual starting in 1993.

\section*{(v) Opening up of government procurement}

In 1986 public sector purchases in the EC accounted for 15 percent of the Community's gross domestic product. However, only a small fraction of those purchases was awarded to companies from other EC countries. Sectors like telecommunications, defense

Figure 4 Decrease in unit costs of production (in percent), as a result of the exploitation of the economies of scale: all countries.
\begin{tabular}{lccc} 
& 1995 & 2000 & 2010 \\
Energy products & 0.4 & & \\
Industrial products & & 0.5 & 0.5 . \\
- Intermediate goods & 2.0 & & 3.0 \\
- Equipment goods & 2.0 & 3.0 & 3.0 \\
- Consumption goods & 0.4 & 0.5 & 3.0 \\
Services (except trade \& government) & 2.0 & 3.0 & 3.0
\end{tabular}

Source: Catinat and Italianer (1988) and authors' estimates.
and transportation are the ones that are guarded the most by government protectionism in procurement markets. The costs associated with these policies are enormous. They start from higher prices that governments pay for products that they could otherwise get more cheaply, and they end up creating a non-competitive and sub-optimal market mechanism.

The internal market program aims to end every kind of protectionism that currently exists and to encourage competition. The effects will initially be static, in the sense that governments will be buying from the cheapest supplier. Dynamic effects will arise because of increased competition as well as because of the exploitation of the economies of scale in many high technology sectors. The result again will be downward pressure on prices. The price reduction effect by sector of this increased competition was estimated by the following formula for all countries:
\[
\left(\text { GOVP }_{i t} / Y_{i t}\right) * \text { GOVEF }_{i}
\]
where \(\mathrm{GOVP}_{\mathrm{it}}\) represents government purchases of sector i products in year \(\mathrm{t}, \mathrm{Y}_{\mathrm{it}}\) gross output of sector \(i\) in year \(t\), and finally, GOVEF, the price reduction coefficients which were assumed to be 0.1 in 1993, 0.25 in 1995 and 0.3 after 2000.

\section*{III. Simulation Results}

The Inforum international system of models was simulated for the period 1992 to 2010. According to the system results, Europe appears on the verge of a very strong growth path. The source of that growth is generally higher productivity growth, which is different across countries at the sectoral level.
(i) Aggregate macroeconomic effects

Tables 1 to 4 show the results for the four Community countries in the Inforum system. Each line represents percentage deviations of the "Europe without borders"
variables (in real terms) from the ones of "Europe with borders" for the years of 1993 through 2010. All four countries show significant increases in real GDP, per capital real income and consumption, exports, investment and imports. Germany, France and Belgium show increases in employment as well. The Italian model has Italy failing to employ all of the workers displaced by higher rates of productivity growth. Prices were also considerably lower with economic integration. In the three models with price sides, consumer prices in 2000 were \(6.2 \%\) lower in Germany, \(4.3 \%\) lower in France and \(7.1 \%\) lower in Italy. The effects build over time and competition and labor efficiencies increase relative to the no integration scenario. The graphs at the bottom of each table are to illustrate the effects of integration over time for gross domestic product and an other macroeconomic variable which is different for each country.

For non-community countries the results tended to be slightly negative. Tables 5, 6 and 7 show the results for the United States, the Republic of Korea and Japan respectively. For all countries the initial effects are positive as exports increase because of greater import demands in Europe but later fall as increased European competitiveness squeezes them out of foreign markets. The graphs for gross domestic product and exports are shown for the United States and Korea together with their respective tables, while for Japan the graphs for exports and relative Japanese export is presented. Real incomes tend to increase because of lower import prices.

\section*{(ii) Industrial effects}

Although the aggregate results are more or less uniform across all four European countries considered, that is not true for the industrial effects. The differences are due to the different sectoral structure of the economies and to the fact that the implemented assumptions involve different treatment of each of the sectors across countries.

A tabulation of sectors in Belgium, France, Germany and Italy where the increases in output are greater than ten percent for the year 2000 , yields the following:

Figure 5 Industrial sectors in Belgium, France, Germany and Italy with increases in output greater than ten percent -- Year 2000.

\section*{Belgium}

Fishery
Milk
Clothing
Paper
Non-motor Repair
Ocean Transport

Coal
Tobacco
Wood \& Furniture
Printing
Coastal Transport

\section*{France}

Glass
Castings
Machine Tools
Industrial Equipment
Ordnance
Office Equipment
Industrial Electrical Equipment
Germany
Non-ferrous Metals
Non-road Vehicles
Textiles

Household Appliances
Motor Vehicles
Precision Instruments
Synthetic Fibers
Ocean Transportation Services
Miscellaneous Transportation Services

Inspection of the lists for France and Germany leads to the following curious result: Germany, a large capital equipment producer, has relatively larger gains in consumer type sectors while more agricultural France sees relatively larger gains in the capital goods industries. Please note that capital spending rises more in Germany than in France (see Tables 1 and 2 respectively), so the reason is not domestically induced spending but rather export/import related. For Belgium, consumption related sectors grow significantly, while no Italian sector experiences a change greater than ten percent.

The industrial effects on the US, Canada, Japan and Korea are summarized in Figure 6 below.

Figure 6 Industrial sectors in the USA, Canada, Japan and Korea with decreases in output greater than one percent and increases greater than a quarter of a percent -- Year 2000.

USA
Output decreases greater than one percent

Ferrous metals
Other non-ferrous
Metalworking machinery
Office equipment

Copper
Engines and turbines
Special Industrial machinery
Electrical industrial apparatus

Communications equipment \(\&\) electronic components
Construction, Mining \& oilfield machinery
Miscellaneous non-electrical machinery
Output increases greater than a quarter of a percent Shoes

Computers
Canada
Output decreases greater than one percent
Yarn and manmade fibers Furniture and fixtures

Iron and steel products
Structural metal products
Agricultural machinery
Motor vehicles
Electrical products ex. radio, TV
Industrial chemicals
Pipeline transport

Aluminum products
Other fabricated metal products
Other industrial machinery
Motor vehicle parts
Non-cement non-metallic minerals
Scientific equipment

Output increases greater than a quarter of a percent
Agricultural products excl. animal \& grain

Fish landings
Crude mineral oils
Misc food products
Pulp
Imputed rent occupied homes

Coal
Fish products
Leather \& leather products
Non-motor vehicle transport equipment
Amusement and recreation

\section*{Japan \\ Output decreases greater than one percent}

Pig iron, crude steel
Electrical machinery
Leather \& fur products
Output increases greater than a quarter of a percent
Synthetic fiber yarns
Synthetic fibers
Korea
Output decreases greater than one percent

Forestry products
Non-metallic ores
Textile fabrics
Leather \& leather products
Synthetic resins
Other chemicals
Rubber products
Iron and steel
Fabricated metal products
Electrical equipment
Electronic appliances
Other electronic components
Output increases greater than a quarter of a percent
Fishery
Transport \& warehousing

Metal ores
Fiber yarn
Fabricated textiles
Basic chemicals
Chemical fibers
Petroleum products
Non-metallic mineral products
Primary non-ferrous metals
Non-electrical machinery
Household electronics
Semi-conductors
Measuring,medical \& optical instruments
Shipbuilding
Education and research

For the United States, only three industrial sectors showed increases in exports of more than one percent with European integration: Coal, Textiles and Computers. Nineteen of the remaining forty-five goods sectors showed export losses of more than one percent. With respect to the output changes, most of the sectors gave negligible increases or decreases. The same is the case for Japan, while for Canada and Korea the magnitude of
the effects by industrial sector seems to be bigger but still not very significant.
Tables 8,9 and 10 show cross country comparisons for three industries: electrical machinery and equipment (including computers), primary metals and ores, and chemicals and plastic products. The results vary significantly by country but in almost all cases, European countries are the gainers and non-European the losers. Specifically, for electrical machinery and equipment, French and Italian output grows the most as export growth surpasses import growth, while United States, Canada, Japan and Korea loose in terms of output. Italy experiences a significant increase in the output of primary metals and ores, which is derived from higher export penetration. Finally, the output of chemicals increases in all European countries together with exports.

\section*{(iii) Comparison of the results with the Cecchini report}

A set of assumptions similar to ours was implemented and simulated by Cecchini (1988) using the HERMES and INTERLINK macroeconometric models. Table 11 compares some of the main aggregate macro results of that study with the ones reported above. In general, the results seem to be in the same direction, although the magnitudes differ in some cases. That could be due to a different set of assumptions (like in the case of Belgium) or to the way the models respond to economic shocks. For all countries, GDP is expected to increase, prices to decline and labor productivity to increase. Employment moves in different directions in France, Germany and Italy. The reason for that is the different way the models react to supply shocks in the short, medium and long run.

\section*{IV. Summary}

The objective of this paper was to address the economic aspects of the 1992 European integration and to estimate its potential effects on the economies of Europe and the rest of the world. A set of assumptions representing the EC directives was developed and introduced in the Inforum interindustry models of Belgium, France, Germany and Italy. Those assumptions include the deregulation of financial services, abolition of border related controls, increased competition, economies of scale and opening up of government procurement.

The results showed that the European economies will experience higher economic growth and per capita income with lower prices and higher labor productivity. For the economies of the rest of the world the integration process is not expected to bring about any significant results. Initially the effects will be positive due mainly to increased exports which will later fall. Moreover, the integration process will generate diverse results across sectors in different countries.

We are grateful to Clopper Almon, Douglas Meade and Josef Richter for extensive comments and suggestions on an earlier version of the paper and to participants of the INFORUM seminar for helpful comments.

\section*{ENDNOTES}
1. Throughout the paper when we talk about Germany we refer to the Federal Republic of Germany.
2. The Spanish model is part of the system, but not fully operational. As a result, the assumptions for Europe 1992 were not incorporated in it. Also, the model of Belgium does not have a price side, thus it does not produce forecasts for prices.
3. Chapter six of the Cecchini report contains a detailed discussion of the costs of nonEurope for the service sectors.

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Table 1: Germany
Aggregate macroeconomic results (percentage deviations from the Europe with borders case)
\begin{tabular}{lcccccccc} 
& 1993 & 1994 & 1995 & 1996 & 1997 & 1998 & 2000 & 2010 \\
Real Gross Product & 3.02 & 4.38 & 3.83 & 3.80 & 3.80 & 4.99 & 6.14 & 6.12 \\
Private Consumption & 3.68 & 6.24 & 5.46 & 4.09 & 4.99 & 6.15 & 6.22 & 7.04 \\
Exports & 2.19 & 2.94 & 3.95 & 4.66 & 4.84 & 6.28 & 7.31 & 8.35 \\
Imports & 5.41 & 7.60 & 6.83 & 6.40 & 5.83 & 6.54 & 6.74 & 8.26 \\
Equipment Investment & 8.55 & 11.25 & 8.28 & 8.94 & 5.23 & 5.96 & 9.76 & 7.89 \\
Employment & 0.38 & 0.07 & 0.61 & 1.00 & 0.22 & 0.23 & 0.45 & -0.15 \\
Aggregate Productivity & 2.62 & 4.32 & 3.17 & 2.77 & 3.57 & 4.76 & 5.70 & 6.22 \\
GNP Deflator & -2.85 & -1.71 & -1.64 & -2.86 & -4.97 & -7.35 & -4.58 & -4.31 \\
Consumer Price Deflator & -3.74 & -3.71 & -3.72 & -4.43 & -6.04 & -8.19 & -6.19 & -6.29 \\
Real Income per capita & 4.0 & 6.3 & 6.2 & 5.1 & 5.2 & 6.3 & 6.7 & 6.9
\end{tabular}


German red disposoble income nobe \(902=100\)


Table 2: France
Aggregate macroeconomic results (percentage deviations from the Europe with borders case)
\begin{tabular}{lcccccccc} 
& 1993 & 1994 & 1995 & 1996 & 1997 & 1998 & 2000 & 2010 \\
Real Gross Product & 1.70 & 2.56 & 3.41 & 3.73 & 3.99 & 4.84 & 5.53 & 6.51 \\
Private Consumption & 0.74 & 1.36 & 2.31 & 2.75 & 3.37 & 3.68 & 4.19 & 4.32 \\
Exports & 3.01 & 4.50 & 5.30 & 6.03 & 6.41 & 8.68 & 10.59 & 13.57 \\
Imports & 3.63 & 4.84 & 6.36 & 6.42 & 6.58 & 7.62 & 7.71 & 7.95 \\
Equipment Investment & 4.68 & 6.45 & 8.57 & 8.04 & 7.18 & 7.96 & 7.21 & 5.20 \\
Employment & 0.65 & 0.57 & 0.48 & 0.40 & 0.28 & 0.60 & 0.38 & 0.74 \\
Aggregate Productivity & 0.97 & 1.97 & 2.87 & 3.33 & 3.72 & 4.21 & 5.09 & 5.74 \\
GNP Deflator & -1.88 & -2.53 & -3.24 & -3.30 & -3.45 & -4.17 & -4.46 & -4.14 \\
Consumer Price Deflator & -1.84 & -2.47 & -3.23 & -3.35 & -3.60 & -4.22 & -4.29 & -4.05 \\
Real Income per capita & 1.4 & 1.9 & 2.8 & 3.2 & 3.6 & 4.2 & 4.5 & 4.9
\end{tabular}


Table 3: Italy
Aggregate macroeconomic results (percentage deviations from the Europe with borders case)
\begin{tabular}{lcccccccc} 
& 1993 & 1994 & 1995 & 1996 & 1997 & 1998 & 2000 & 2010 \\
Real Gross Product & 1.58 & 1.88 & 1.94 & 2.58 & 1.82 & 3.16 & 2.87 & 4.58 \\
Private Consumption & 1.92 & 2.75 & 3.43 & 4.00 & 3.91 & 6.05 & 5.89 & 5.86 \\
Exports & 1.68 & 2.47 & 2.77 & 3.03 & 3.26 & 3.91 & 5.36 & 9.37 \\
Imports & 4.29 & 5.22 & 6.00 & 6.87 & 5.96 & 9.32 & 8.52 & 8.66 \\
Equipment Investment & 4.00 & 4.34 & 4.19 & 6.19 & 2.83 & 5.37 & 3.41 & 5.11 \\
Employment & 0.36 & 0.14 & -0.80 & -0.77 & -1.52 & -1.00 & -1.77 & -0.68 \\
Aggregate Productivity & 1.22 & 1.73 & 2.76 & 3.38 & 3.40 & 4.21 & 4.73 & 5.29 \\
GNP Deflator & 0.53 & -0.67 & -2.06 & -3.09 & -3.88 & -3.29 & -5.15 & -7.83 \\
Consumer Price Deflator & -0.55 & -1.92 & -3.54 & -4.79 & -5.52 & -6.11 & -7.26 & -9.88 \\
Real Income per capita & 2.10 & 2.75 & 2.88 & 3.19 & 2.52 & 4.74 & 3.53 & 4.12
\end{tabular}


Table 4: Belgium
Aggregate macroeconomic results (percentage deviations from the Europe with borders case)
\begin{tabular}{lcccccccc} 
& 1993 & 1994 & 1995 & 1996 & 1997 & 1998 & 2000 & 2010 \\
Real Gross Product & 2.85 & 4.40 & 5.54 & 5.56 & 5.08 & 5.35 & 5.66 & 5.81 \\
Private Consumption & 0.59 & 1.99 & 3.01 & 3.47 & 3.60 & 3.65 & 4.32 & 3.75 \\
Exports & 5.45 & 7.60 & 8.31 & 8.36 & 8.38 & 9.46 & 9.74 & 11.85 \\
Imports & 5.77 & 7.94 & 8.86 & 8.26 & 7.72 & 8.55 & 8.88 & 10.12 \\
Equipment Investment & 6.91 & 10.06 & 14.64 & 12.96 & 9.06 & 7.96 & 7.93 & 5.70 \\
Employment & 0.61 & 1.62 & 1.82 & 2.01 & 1.32 & 0.81 & 0.35 & 0.49 \\
Aggregate Productivity & 2.17 & 2.68 & 3.71 & 3.49 & 3.80 & 4.60 & 5.29 & 5.33 \\
Real Income per capita & 0.88 & 2.77 & 3.94 & 4.47 & 4.30 & 4.06 & 4.49 & 3.98
\end{tabular}



Table 5: United States
Aggregate macroeconomic results (percentage deviations from the Europe with borders case)
\begin{tabular}{lcccccccc} 
& 1993 & 1994 & 1995 & 1996 & 1997 & 1998 & 2000 & 2010 \\
Real Gross Product & 0.15 & 0.20 & 0.07 & -0.09 & -0.10 & -0.04 & -0.16 & -0.01 \\
Private Consumption & 0.10 & 0.21 & 0.14 & 0.09 & 0.16 & 0.22 & 0.17 & 0.26 \\
Exports & 0.41 & 0.41 & 0.14 & -0.23 & -0.56 & -0.63 & -1.04 & -0.78 \\
Imports & 0.31 & 0.43 & 0.30 & 0.22 & 0.34 & 0.53 & 0.45 & 0.70 \\
Equipment Investment & 0.62 & 0.78 & 0.19 & -0.52 & -0.54 & -0.08 & -0.24 & 0.55 \\
Employment & 0.08 & 0.16 & 0.11 & -0.01 & -0.04 & 0.00 & -0.05 & -0.00 \\
Aggregate Productivity & 0.06 & 0.04 & -0.03 & -0.06 & -0.04 & -0.03 & -0.09 & 0.01 \\
GNP Deflator & 0.00 & 0.00 & 0.04 & 0.04 & 0.00 & -0.08 & -0.04 & -0.25 \\
Consumer Price Deflator & -0.03 & -0.02 & 0.02 & 0.00 & -0.10 & -0.19 & -0.17 & -0.37 \\
Real Income per capita & 0.13 & 0.23 & 0.12 & -0.01 & -0.02 & 0.09 & 0.02 & 0.09
\end{tabular}



Table 6: Republic of Korea
Aggregate macroeconomic results (percentage deviations from the Europe with borders case)
\begin{tabular}{lcccccccc} 
& 1993 & 1994 & 1995 & 1996 & 1997 & 1998 & 2000 & 2010 \\
Real Gross Product & 0.05 & 0.02 & -0.10 & -0.20 & -0.29 & -0.36 & -0.49 & -0.47 \\
Private Consumption & 0.04 & 0.07 & 0.24 & 0.40 & 0.41 & 0.43 & 0.45 & 0.43 \\
Exports & 0.11 & -0.01 & -0.54 & -1.08 & -1.42 & -1.63 & -2.11 & -2.03 \\
Imports & 0.10 & 0.02 & -0.19 & -0.33 & -0.36 & -0.39 & -0.47 & -0.21 \\
Equipment Investment & 0.06 & -0.01 & -0.20 & -0.35 & -0.35 & -0.45 & -0.49 & -0.35 \\
Employment & 0.03 & 0.02 & -0.04 & -0.11 & -0.18 & -0.23 & -0.32 & -0.28 \\
Aggregate Productivity & 0.00 & 0.00 & -0.07 & -0.07 & -0.07 & -0.13 & -0.18 & -0.18 \\
GNP Deflator & -0.06 & -0.06 & -0.05 & 0.05 & 0.05 & 0.09 & 0.16 & 0.18 \\
Consumer Price Deflator & -0.13 & -0.12 & -0.17 & -0.10 & -0.14 & -0.09 & -0.04 & -0.05 \\
Real Income per capita & 0.10 & 0.11 & 0.13 & 0.12 & 0.17 & 0.14 & 0.06 & 0.10
\end{tabular}


Table 7: Japan
Aggregate macroeconomic results (percentage deviations from the Europe with borders case)
\begin{tabular}{lcccccccc} 
& 1993 & 1994 & 1995 & 1996 & 1997 & 1998 & 2000 & 2010 \\
Real Gross Product & 0.02 & 0.01 & -0.07 & -0.09 & -0.11 & -0.12 & -0.21 & -0.08 \\
Private Consumption & -0.04 & 0.03 & 0.12 & 0.14 & 0.20 & 0.22 & 0.16 & 0.30 \\
Exports & 0.27 & 0.06 & -0.61 & -0.83 & -1.16 & -1.25 & -1.59 & -0.80 \\
Imports & 0.07 & 0.11 & 0.05 & 0.02 & 0.03 & 0.08 & 0.02 & 0.57 \\
Equipment Investment & 0.00 & 0.02 & 0.02 & -0.01 & 0.01 & 0.01 & -0.02 & 0.02 \\
Employment & 0.01 & 0.02 & -0.05 & -0.06 & -0.08 & -0.08 & -0.18 & -0.03 \\
Aggregate Productivity & 0.00 & -0.01 & -0.02 & -0.03 & -0.04 & -0.04 & -0.03 & -0.05 \\
GNP Deflator & 0.00 & 0.00 & -0.09 & -0.18 & -0.26 & -0.34 & -0.48 & 0.00 \\
Consumer Price Deflator & 0.09 & 0.00 & -0.18 & -0.27 & -0.35 & -0.42 & -0.32 & -0.12 \\
Real Income per capita & -0.04 & 0.04 & 0.10 & 0.12 & 0.18 & 0.19 & 0.13 & 0.29
\end{tabular}


Table 8: All system countries
Industrial effects - Electrical goods (including computers)
(Percentage deviations from the Europe with borders case)
\(\begin{array}{llllllll}1993 & 1994 & 1995 & 1996 & 1997 & 1998 & 2000 & 2010\end{array}\)

\section*{OUTPUTS}
\begin{tabular}{lrrrrrrrr} 
Germany & 3.60 & 4.87 & 4.62 & 5.75 & 3.97 & 5.19 & 8.14 & 6.99 \\
France & 2.20 & 3.24 & 4.24 & 5.03 & 4.86 & 6.65 & 8.40 & 9.95 \\
Italy & 2.77 & 2.08 & 2.09 & 3.51 & 1.46 & 4.20 & 3.61 & 9.17 \\
Belgium & 4.94 & 6.38 & 7.11 & 4.79 & 3.13 & 3.94 & 4.09 & 3.14 \\
United States & 0.54 & 0.58 & 0.16 & -0.38 & -0.61 & -0.44 & -0.76 & -0.26 \\
Canada & 0.00 & -0.38 & -1.38 & -1.78 & -2.15 & -2.23 & -3.07 & -2.13 \\
Japan & 0.14 & -0.06 & -0.54 & -0.63 & -0.81 & -0.85 & -1.13 & -0.67 \\
South Korea & 0.08 & -0.25 & -0.85 & -1.38 & -1.64 & -1.81 & -2.20 & -1.66
\end{tabular}

EXPORTS
\begin{tabular}{lcccccccc} 
Germany & 2.02 & 2.60 & 3.48 & 4.55 & 3.77 & 4.78 & 5.55 & 6.63 \\
France & 2.96 & 4.31 & 5.05 & 5.84 & 5.70 & 8.04 & 9.28 & 11.79 \\
Italy & 1.82 & 2.80 & 3.41 & 3.91 & 4.23 & 5.38 & 7.63 & 13.81 \\
Belgium & 3.05 & 4.23 & 4.53 & 4.79 & 4.30 & 5.03 & 4.96 & 4.71 \\
United States & 0.78 & 0.76 & 0.45 & -0.11 & -0.67 & -0.67 & -1.18 & -0.88 \\
Canada & -0.10 & -0.62 & -2.10 & -2.74 & -3.41 & -3.52 & -4.42 & -3.22 \\
Japan & 0.28 & -0.07 & -0.93 & -1.14 & -1.52 & -1.62 & -2.14 & -1.19 \\
South Korea & 0.12 & -0.30 & -1.10 & -1.89 & -2.31 & -2.52 & -3.12 & -2.47 \\
& \multicolumn{4}{c}{ IMPORTS } & & & & \\
\end{tabular}
\begin{tabular}{lrrrrrrrr} 
Germany & 6.52 & 8.34 & 6.39 & 6.32 & 4.70 & 6.00 & 6.02 & 7.48 \\
France & 4.21 & 5.88 & 8.25 & 8.63 & 8.41 & 9.52 & 9.70 & 8.54 \\
Italy & 8.53 & 6.99 & 7.63 & 10.81 & 4.41 & 10.80 & 5.67 & 10.13 \\
Belgium & 7.16 & 9.27 & 10.62 & 7.62 & 5.38 & 6.36 & 6.65 & 6.00 \\
United States & 0.37 & 0.52 & 0.33 & 0.17 & 0.22 & 0.47 & 0.46 & 0.79 \\
Canada & -0.10 & -0.62 & -2.10 & -2.74 & -3.41 & -3.52 & -4.42 & -3.22 \\
Japan & 0.20 & 0.25 & 0.11 & -0.00 & -0.13 & -0.08 & -0.10 & 0.89 \\
South Korea & 0.11 & -0.14 & -0.59 & -0.89 & -0.99 & -1.05 & -1.28 & -0.81
\end{tabular}

Table 9: All system countries
Industrial effects - Primary metals and ores
(Percentage deviations from the Europe with borders case)
\(\begin{array}{llllllll}1993 & 1994 & 1995 & 1996 & 1997 & 1998 & 2000 & 2010\end{array}\)

\section*{OUTPUTS}
\begin{tabular}{lcccccccc} 
Germany & 3.16 & 3.83 & 3.62 & 4.03 & 3.73 & 5.89 & 8.26 & 7.05 \\
France & 1.77 & 2.31 & 2.62 & 2.78 & 2.46 & 3.43 & 4.35 & 6.08 \\
Italy & 5.31 & 5.44 & 4.67 & 7.41 & 4.37 & 7.63 & 7.85 & 19.07 \\
Belgium & 3.99 & 5.31 & 5.88 & 5.40 & 3.89 & 4.20 & 4.44 & 3.92 \\
United States & 0.26 & 0.19 & -0.14 & -0.47 & -0.53 & -0.48 & -0.77 & -0.34 \\
Canada & 0.28 & 0.30 & -0.21 & -0.46 & -0.79 & -0.74 & -1.13 & -0.78 \\
Japan & 0.04 & 0.01 & -0.15 & -0.26 & -0.36 & -0.44 & -0.57 & -0.55 \\
South Korea & 0.08 & -0.25 & -0.85 & -1.38 & -1.64 & -1.81 & -2.20 & -1.66 \\
& & EXPORTS & & & & & \\
Germany & 1.97 & 2.57 & 3.58 & 4.10 & 4.35 & 5.83 & 6.87 & 7.43 \\
France & 2.08 & 3.20 & 3.46 & 4.04 & 3.89 & 4.79 & 5.83 & 8.24 \\
Italy & 2.25 & 3.16 & 3.60 & 4.21 & 4.35 & 5.34 & 6.79 & 10.61 \\
Belgium & 4.46 & 6.18 & 6.49 & 6.89 & 5.61 & 5.92 & 6.47 & 6.58 \\
United States & 0.48 & 0.46 & 0.35 & 0.05 & -0.33 & -0.43 & -0.68 & -0.48 \\
Canada & 0.35 & 0.39 & 0.11 & -0.13 & -0.34 & -0.27 & -0.24 & -0.05 \\
Japan & 0.05 & -0.14 & -0.47 & -1.01 & -1.29 & -1.62 & -1.88 & -1.50 \\
South Korea & 0.34 & 0.36 & -0.04 & -0.59 & -0.86 & -0.94 & -1.42 & -1.12 \\
& & IMPORTS & & & & & \\
Germany & 4.57 & 6.66 & 5.97 & 6.39 & 5.48 & 5.32 & 5.53 & 7.79 \\
France & 4.39 & 5.98 & 7.81 & 7.78 & 7.76 & 9.41 & 10.22 & 11.78 \\
Italy & 0.00 & 0.00 & 0.00 & 0.01 & 0.01 & 0.01 & 0.01 & -0.07 \\
Belgium & 7.02 & 9.32 & 10.50 & 9.97 & 7.91 & 8.61 & 9.12 & 9.08 \\
United States & 0.55 & 0.86 & 0.79 & 0.52 & 0.55 & 0.82 & 0.76 & 1.38 \\
Canada & 0.35 & 0.39 & 0.11 & -0.13 & -0.34 & -0.27 & -0.24 & -0.05 \\
Japan & 0.06 & -0.09 & -0.44 & -0.47 & -0.43 & -0.31 & -0.48 & 0.21 \\
South Korea & 0.17 & 0.14 & 0.05 & 0.02 & 0.18 & 0.30 & 0.37 & 1.02 \\
& & & & & & & &
\end{tabular}

Table 10: All system countries Industrial effects - Chemicals and plastic products (Percentage deviations from the Europe with borders case)
\(\begin{array}{llllllll}1993 & 1994 & 1995 & 1996 & 1997 & 1998 & 2000 & 2010\end{array}\)
OUTPUTS
\begin{tabular}{lrrrrrrrr} 
Germany & 1.91 & 2.33 & 2.95 & 3.88 & 4.57 & 7.01 & 9.37 & 9.33 \\
France & 1.71 & 2.86 & 3.68 & 4.09 & 4.43 & 5.36 & 5.99 & 7.53 \\
Italy & 1.34 & 1.48 & 1.48 & 2.24 & 1.74 & 3.54 & 3.74 & 6.85 \\
Belgium & 3.86 & 5.48 & 6.32 & 6.26 & 5.90 & 6.57 & 6.69 & 6.79 \\
United States & 0.13 & 0.13 & -0.13 & -0.39 & -0.48 & -0.49 & -0.71 & -0.50 \\
Canada & 0.08 & -0.26 & -0.77 & -1.05 & -1.25 & -1.37 & -1.76 & -0.87 \\
Japan & 0.02 & -0.06 & -0.21 & -0.23 & -0.31 & -0.31 & -0.46 & -0.42 \\
South Korea & 0.12 & 0.07 & -0.52 & -1.10 & -1.52 & -1.83 & -2.32 & -2.15
\end{tabular}

EXPORTS
\begin{tabular}{lrrrrrrrr} 
Germany & 2.25 & 3.09 & 5.29 & 6.49 & 7.18 & 9.17 & 11.19 & 10.96 \\
France & 2.94 & 4.30 & 5.11 & 5.54 & 5.87 & 7.19 & 7.65 & 9.72 \\
Italy & 1.25 & 2.09 & 2.71 & 3.27 & 4.06 & 5.29 & 7.48 & 13.55 \\
Belgium & 4.79 & 6.77 & 7.70 & 7.91 & 7.70 & 8.59 & 8.66 & 9.27 \\
United States & 0.31 & 0.38 & -0.22 & -0.75 & -1.22 & -1.48 & -1.98 & -1.48 \\
Canada & -0.08 & -0.65 & -1.39 & -1.93 & -2.29 & -2.55 & -3.11 & -2.11 \\
Japan & 0.20 & 0.12 & -0.10 & -0.11 & -0.43 & -0.41 & -0.62 & 0.61 \\
South Korea & 0.33 & 0.28 & -1.02 & -2.61 & -3.72 & -4.61 & -5.74 & -5.13
\end{tabular}

\section*{IMPORTS}

Germany
France
Italy
Belgium
United States
Canada
Japan
South Korea
\begin{tabular}{rrrrrrrr}
5.89 & 8.15 & 8.69 & 8.47 & 7.96 & 8.53 & 8.26 & 9.04 \\
3.05 & 4.05 & 5.17 & 5.62 & 6.20 & 7.45 & 7.99 & 9.06 \\
4.58 & 6.04 & 7.25 & 8.14 & 7.10 & 9.34 & 8.64 & 9.93 \\
4.31 & 6.07 & 7.09 & 7.15 & 6.97 & 7.76 & 7.96 & 8.86 \\
0.48 & 0.78 & 0.85 & 0.89 & 1.06 & 1.34 & 1.29 & 1.52 \\
-0.08 & -0.65 & -1.39 & -1.93 & -2.29 & -2.55 & -3.11 & -2.11 \\
0.07 & 0.14 & 0.11 & 0.08 & 0.06 & 0.10 & -0.01 & 0.72 \\
0.09 & 0.07 & -0.23 & -0.44 & -0.57 & -0.64 & -0.85 & -0.80
\end{tabular}

Table 11: Comparison of our results with the Cecchini report
Aggregate macroeconomic results (percentage deviations from the Europe with borders case)

1993
1995
1998
This study Cecchini This study Cecchini This study Cecchini
BELGIUM \({ }^{*}\)
\begin{tabular}{lllllll} 
GDP & 2.85 & 1.23 & 5.54 & 2.25 & 5.35 & 2.34 \\
Labor productivity & 2.17 & 0.85 & 3.71 & 0.85 & 4.60 & 0.66 \\
Employment & 0.61 & 0.16 & 1.82 & 1.00 & 0.81 & 1.31
\end{tabular}

FRANCE
\begin{tabular}{lrrrrrr} 
GDP & 1.70 & 1.09 & 3.41 & 2.88 & 4.84 & 5.05 \\
Consumpt. deflat. & -1.84 & -1.00 & -3.23 & -2.43 & -4.22 & -4.89 \\
Labor productivity & 0.97 & 1.37 & 2.87 & 2.56 & 4.21 & 3.54 \\
Employment & 0.65 & -0.28 & 0.48 & 0.34 & 0.60 & 1.57
\end{tabular}

GERMANY
GDP \(\quad 3.02 \quad 1.22\)
Consumpt. deflat. -3.74 -0.74
Labor productivity \(2.62 \quad 1.53\)
Employment \(\quad 0.38 \quad-0.31\)
\begin{tabular}{rrrr}
3.83 & 2.57 & 4.99 & 4.20 \\
-3.72 & -2.30 & -8.19 & -6.16 \\
3.17 & 2.07 & 4.76 & 2.51 \\
0.61 & 0.50 & 0.23 & 1.68
\end{tabular}

ITALY
\begin{tabular}{lrrrrrr} 
GDP & 2.04 & 1.35 & 2.27 & 4.54 & 3.47 & 5.46 \\
Consumpt. defiat. & -0.91 & -2.30 & -3.94 & -5.55 & -5.52 & -7.07 \\
Labor productivity & 1.44 & 1.94 & 3.05 & 4.20 & 4.81 & 3.89 \\
Employment & 0.59 & -0.62 & -0.76 & 0.26 & -1.28 & 1.40
\end{tabular}

\footnotetext{
* The Cecchini results for Belgium do not include assumptions (iii) and (iv) i.e. increased competition and economies of scale.
}

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Paper for
The Tenth International Conference on Input-Output Technique

\title{
Paper for the Tenth International Conference on Input-Output Techniques
}

INPUT-OUTPUT ANATOMY OF CHINA'S ENERGY-DEMAND CHANGES, 1981-1987

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Energy consumption typically grows faster than economic output in developing countries because most major changes associated with development--industrialization, increases in the capital-to-labor ratio, substitution of commercial energy for traditional energy, the construction of modern infrastructure, motorization, and urbanization--point towards an increased energy intensity (Lin, 1991). \({ }^{1}\) Between 1973 and 1988 , for example, commercial energy consumption grew about 20 percent more than gross domestic product (GDP) for the developing countries as a whole (Levine et al., 1991). China's economic development in the 1980s, however, did not follow this pattern. Between 1980 and 1988 , China's gross domestic product (GDP) grew at about 10 percent annually, but energy consumption grew by only 5 percent a year. Energy intensity, in grams of standard coal equivalent per yuan of GDP (in 1980 constant prices), decreased by almost 30 percent from 1,348 in 1980 to 947 in 1988 (Polenske and Lin, forthcoming).

At the MIT multiregional planning research staff, we are studying how this drop in China's energy intensity occurred between 1981 and 1987, the years for which we have input-output tables, and WE are examining factors that were primarily responsible for the energy-intensity reduction. Using a structural decomposition analysis, we are investigating two questions: (1) How

\footnotetext{
\({ }^{1}\) Unless otherwise noted, the term "energy" in this paper refers to commercial energy.
}
did energy demand change in China's economy between 1981 and 1987? and (2) How much of this change could be attributed to final-demand shifts (changes in what to consume) and/or to production-technology changes (changes in how to produce)? We focus our analysis on material-production sectors-agriculture, industry, construction, transportation, and commerce-which accounted for about 80 percent of total primary energy consumption and over 80 percent of GDP in 1987 (Polenske and Lin, forthcoming). Our analytical framework includes all material-production sectors of the economy and covers the entire energy production and consumption cycle from mining, refining, transporting, converting, distributing, to end-use.

In this paper, we describe our model formulation and present some of the preliminary results from our structural decomposition analysis of energydemand changes in China's material production sectors.

\section*{STRUCTURAL DECOMPOSITION ANALYSIS: AN ALTERNATIVE FORMOLATION}

We employ the structural decomposition analysis--a comparative inputoutput analysis--to identify specific factors behind the energy-intensity changes and relative contribution of each individual factor. This approach dates from the work of Leontief (1941) and Chenery et al. (1962), who examined changing economic structures. It has been widely used in energy studies (for example, Bullard and Herendeen, 1975; Park, 1982; Casler and Hannon, 1989; OTA, 1990). Recently Rose and Chen (1991) made an important contribution to advance the state-of-the-art of the structural decomposition analysis. They extend the analysis to a two-tier KLEM flexible production-function framework, which produces 11 separate sources of energy-use changes and three

\footnotetext{
"interactive" effects. They also formally derive a system of estimating
}
equations that are mutually exclusive and completely exhaustive. The empirical application of their model in studying energy-demand changes in the United States between 1972-1982 (Rose and Chen, 1991) and in Taiwan between 1971 and 1984 (Chen and Rose, 1990) shows that, overall, the model can yield as much insight as more elaborate and data-intensive KLEM econometric models of production technologies.

We adopt the Rose-Chen approach of systematic derivation of "mutually exclusive and completely exhaustive equations," but use a different formulation. We start our model formulation from a standard static inputoutput table.

\section*{The Model Structure}

An input-output table provides a detailed statistical account of the flows of goods and services among the producers and purchasers of an economy. It stems from the double-accounting principles employed in the national income and product accounts. Gross output can be accounted for either by adding the total purchases of intermediate inputs, labor, capital and imports, or by tracing the flows of output from sectoral sources to destinations of intermediate and final users. Mathematically, an input-output table can be expressed as:
\[
\begin{equation*}
A X+X=Y \tag{1}
\end{equation*}
\]
where \(X=a\) vector of gross output,
\(Y=a\) vector of final demand, and
\(A=a \operatorname{matrix}\) of direct input coefficients, which show the inputs required to produce one unit of gross output.

The product of \(A\) and \(X\) (i.e., AX) indicates the intermediate outputs or inputs--the amount of output that are used by production sectors to deliver final goods and services. We can rearrange Equation (1) to calculate the
total amount of inputs required to provide particular sets of final goods and services:
\[
\begin{equation*}
X=(I-A)^{-1} Y \tag{2}
\end{equation*}
\]
where \(\left(I-A_{t}\right)^{-1}=\) a matrix of total input requirements, which are inputs required to produce one unit of final demand.

For an energy input-output model, the monetary flows in the energy rows in Equation (2) are replaced with the amount of energy in physical units to construct the energy flows accounting identity, which conforms with energy balance condition (Miller and Blair, 1986):
\[
\begin{equation*}
E_{1}+E_{y}=T E \tag{3}
\end{equation*}
\]
where \(E_{i}=\) a vector of intermediate energy consumption,
\(E_{y}=a\) vector of final energy consumption, and
TE = a vector of total domestic energy production.

Using the relationship expressed in Equation (1), we can rewrite energy balance condition of Equation (3) as
\[
\begin{equation*}
e A X+e Y=e X \tag{4}
\end{equation*}
\]

In Equation (4), matrix e selects the energy rows from the input-output table. It is composed of ones and zeros, ones appear in the column locations corresponding to energy sectors and all other elements of the matrix are zeros.

In our research, we focus on energy for production purposes or intermediate energy demand, which equals:
\[
\begin{align*}
E_{1} & =e A X \\
& =e X-e Y \\
& =e(X-Y) \tag{5}
\end{align*}
\]

Substituting \(X\) in Equation (5) with Equation (2) and defining \(F=e\left[(1-A)^{-1}-I\right]\) to simplify the notation, we have
\[
\begin{align*}
&-6 \\
& E_{1}=e\left[(I-A)^{-1} Y-Y\right] \\
&=e\left[(I-A)^{-1}-I\right] Y  \tag{6}\\
&=F Y
\end{align*}
\]

The change in energy consumption over time, then, can be expressed as:
\[
\begin{equation*}
E_{1, t}-E_{1, t-1}-F_{t} Y_{t}-F_{t-1} Y_{t-1} \tag{7}
\end{equation*}
\]

From Equation (7), we can separate energy-demand changes into two major factors: (1) changes in what to consume (final-demand shift) and (2) changes in how to produce (production-technology change). Algebraically,
\[
\begin{array}{rlr}
\Delta E_{1}= & F_{t} Y_{t}-F_{t-1} Y_{t-1} & \\
& F_{t-1}\left(Y_{t}-Y_{t-1}\right) & \text { (Final-Demand Shift) } \\
& +\left(F_{t}-F_{t-1}\right) Y_{t-1} \quad \text { (Production-Technology Change) } \\
& +\left(F_{t}-F_{t-1}\right)\left(Y_{t}-Y_{t-1}\right) \quad \text { (Interaction of Demand Shift and } \\
& & \text { Technology Change) }
\end{array}
\]

The final-demand shift indicates the energy impact of changing final-demand levels and/or mix while holding the production technology constant.

Production-technology change measures the energy impact of changes in the production technology with a given final demand. The third item in Equation (9) represents the interaction between the demand shift and technology change, which is totally independent of the final-demand shift and productiontechnology changes. It shows the change in energy use that results from the simultaneous changes in final demand and in production technology. This could happen, for example, if consumers spend increasing amounts of income on specific types of television sets that are produced with an improved technology.

We can further decompose the final-demand shift into the effect associated with changes in the level of final demand (level effect) and that associated with changes in the mix of final demand (mix effect).
\[
\begin{align*}
& \Delta E_{i, Y}=F_{t-1}\left(Y_{t}-Y_{t-1}\right)  \tag{9}\\
& -F_{t-1}\left[M_{t} L_{t}-M_{t-1} L_{t-1}\right] \\
& =F_{t-1}\left[M_{t-1}\left(L_{t}-L_{t-1}\right)+\left(M_{t}-M_{t-1}\right) L_{t-1}+\left(M_{t}-M_{t-1}\right)\left(L_{t}-L_{t-1}\right)\right] \\
& \text { - } F_{t-1} M_{t-1}\left(L_{t}-L_{t-1}\right) \quad \text { (Demand-Level Effect) } \\
& +F_{t-1}\left(M_{t}-M_{t-1}\right) L_{t-1} \quad \text { (Demand-Mix Effect) } \\
& +F_{t-1}\left(M_{t}-M_{t-1}\right)\left(L_{t}-L_{t-1}\right) \text { (Interaction of the Level and Mix) }
\end{align*}
\]
where \(M_{t}, M_{t-1}=A\) vetor of final-demand mix in year \(t, t-1\); and
\(L_{t}, L_{t-1}=\) Total final demand in year \(t, t-1\).
The second item in Equation (8) measures the energy effect of production-technology changes, which can be rewritten as:
\[
\begin{align*}
& \Delta E_{1, P}=\left(F_{t}-F_{t-1}\right) Y_{t-1} \\
= & e\left[\left(G_{t}-I\right)-\left(G_{t-1}-I\right)\right] Y_{t-1} \\
= & e\left(G_{t}-G_{t-1}\right) Y_{t-1}
\end{align*}
\]
where \(G_{t}=\left(I-A_{t}\right)^{-1}, G_{t-1}=\left(I-A_{t-1}\right)^{-1}\).
It follows that
\(G_{t}\left(I-A_{t}\right)=G_{t-1}\left(I-A_{t-1}\right)=I\)
\(G_{t}\left(I-A_{t}\right)-G_{t-1}\left(I-A_{t-1}\right)=0\)
\(G_{t}-G_{t} A_{t}-G_{t-1}+G_{t-1} A_{t-1}=0\)
\(G_{t}-G_{t-1}=G_{t} A_{t}-G_{t-1} A_{t-1}\)
\(=G_{t} A_{t}-G_{t} A_{t-1}+G_{t} A_{t-1}-G_{t-1} A_{t-1}\)
\(=G_{t}\left(A_{t}-A_{t-1}\right)+\left(G_{t}-G_{t-1}\right) A_{t-1}\)
\(G_{t}-G_{t-1}-\left(G_{t}-G_{t-1}\right) A_{t-1}=G_{t}\left(A_{t}-A_{t-1}\right)\)
\(\left(G_{t}-G_{t-1}\right)\left(I-A_{t-1}\right)-G_{t}\left(A_{t}-A_{t-1}\right)\)
\(G_{t}-G_{t-1}=G_{t}\left(A_{t}-A_{t-1}\right)\left(I-A_{t-1}\right)^{-1}\)
\(=G_{t}\left(A_{t}-A_{t-1}\right) G_{t-1}\)

Inserting Equation (11) into Equation (10) results in
\(\Delta E_{1, P}=\left(F_{t}-F_{t-1}\right) Y_{t-1}\)
\(=e\left(G_{t}-G_{t-1}\right) Y_{t-1}\)
\(=e G_{t}\left(A_{t}-A_{t-1}\right) G_{t-1} Y_{t-1}\)
We can use Equation (12) to separate the effect of changes in direct energy requirements and direct nonenergy requirements of energy use by partitioning and writing the change in the \(\left(A_{t}-A_{t-1}\right)\) as
\[
A_{t}-A_{t-1}=\left(A_{t, E}-A_{t-1, E}\right)+\left(A_{t, M}-A_{t-1, M}\right)
\]
where \(A_{E}\) represents the energy rows of the technical coefficient matrix and \(A_{4}\) represents the material or nonenergy rows. Equation (12) then becomes
\[
\begin{align*}
\Delta E_{1, P}= & e G_{t}\left(A_{t}-A_{t-1}\right) G_{t-1} Y_{t-1}  \tag{13}\\
= & e G_{t}\left(A_{t, E}-A_{t-1, E}\right) G_{t-1} Y_{t-1}+ \\
& (\text { changes in energy inputs) } \\
& e G_{t}\left(A_{t, M}-A_{t-1, M}\right) G_{t-1} Y_{t-1} \\
& (\text { changes in nonenergy inputs) }
\end{align*}
\]

Applying the logic of Equation (13) to individual industries or industry groups--in this case, agriculture, energy, nonenergy industrial sector, construction, transportation, and commerce, we can identify productiontechnology changes in individual sectors and assess their relative contribution to intermediate energy-demand changes. Mathematically,
\[
\begin{align*}
\Delta E_{1, P}= & \Sigma E_{i}^{j}  \tag{14}\\
= & j \text { [ } \quad \text { GG }\left(A_{t, E^{j}}^{j}-A_{t-1, E^{j}}\right) G_{t-1} Y_{t-1}+ \\
& j \text { (changes in energy inputs) } \\
& \left.\quad \text { e } G_{t}\left(A_{t, M}{ }^{j}-A_{t-1, M^{j}}\right) G_{t-1} Y_{t-1}\right] \\
& \quad \text { (changes in nonenergy inputs) }
\end{align*}
\]
where \(E_{1}{ }^{j}\) is the change in energy use due to production-technology changes in sector \(\mathbf{j}\).

We sumarize the hierarchical structure of the estimation equations or factors of energy-demand changes in Table 1

TABLE 1
STRUCTURAL DECOMPOSITION OF INTERMEDIATE ENERGY-DEMAND CHANGE
\begin{tabular}{|c|c|}
\hline Factor & Equation \\
\hline Final-Demand Shift & \(F_{t-1}\left(Y_{t}-Y_{t-1}\right)=F_{t-1}\left(M_{t} I_{t}-M_{t-1} L_{t-1}\right)\) \\
\hline Level Effect & \(F_{t-1} \mathrm{M}_{t-1}\left(L_{t}-L_{t-1}\right)\) \\
\hline Mix Effect & \(F_{t-1}\left(M_{t}-M_{t-1}\right) L_{t-1}\) \\
\hline Interaction of the & \\
\hline Level and Mix & \(F_{t-1}\left(M_{t}-M_{t-1}\right)\left(L_{t}-L_{t-1}\right)\) \\
\hline Production-Technology Change & \(\left(F_{t}-F_{t-1}\right) Y_{t-1}=e G_{t}\left(A_{t}-A_{t-1}\right) G_{t-1} Y_{t-1}\) \\
\hline Energy Inputs & eG \({ }_{t}\left(A_{t, E}-A_{t-1, E}\right) G_{t-1} Y_{t-1}\) \\
\hline Nonenergy Inputs & \(e G_{t}\left(A_{t, M}-A_{t-1, M}\right) G_{t-1} Y_{t-1}\) \\
\hline & \\
\hline \begin{tabular}{l}
Energy Inputs \\
Nonenergy inputs
\end{tabular} & \[
\begin{aligned}
& e G_{t}\left(A_{t, E^{j}}-A_{t-1, E^{j}}^{j}\right) G_{t-1} Y_{t-1} \\
& \left.e G_{t}\left(A_{t-M^{j}}-A_{t-1, ~}^{j}\right) G_{t-1}\right) Y_{t-1}
\end{aligned}
\] \\
\hline Interact of Demand Shift and Technology Change & \(\left(F_{t}-F_{t-1}\right)\left(Y_{t}-Y_{t-1}\right)\) \\
\hline Total & \(E_{t}-E_{t-1}=F_{t} Y_{t}-F_{t-1} Y_{t-1}\) \\
\hline
\end{tabular}

Source: the Authors.

\section*{Data Sources}

To implement our model structure and conduct the structural-decomposition analysis, we require three key data components for both 1981 and 1987: input-output tables, price indices, and energy-flow data.

\section*{Input-Output Tables}

The input-output tables used in this study are commodity-by-commodity tables for the People's Republic of China for 1981 and 1987 under the material-production system of accounts. Due to definitional and methodological changes, these tables had to be modified to achieve consistency.

China compiled two sets of input-output tables in 1981, one based on the industry-by-industry method and the other on the commodity-by-commodity method. The 1981 tables were based on the material production system (MPS) of accounts; therefore, they included only material-production sectors-agriculture, industry, construction, transportation, and comerce--and excluding service-producing sectors. In 1987, China shifted to the System of National Accounts (SNA), but also compiled a table that was consistent with the MPS. They used the commodity-by-commodity method for the 1987 tables. To make the tables in the two years consistent, we chose commodity-by-commodity tables under MPS.

The two years also had different industrial classifications. We aggregated industries into 22 sectors to make the 1981 and 1987 tables comparable. Table 2 provides the names of the 22 sectors and their corresponding standard industrial classification codes (SIC) in 1981 and 1987 tables.

TABLE 2

STANDARD INDUSTRIAL-CLASSIFICATION (SIC) CONVERSION TABLE FOR CHINA'S 1981 AND 1987 INPUT-OUTPUT TABLE


Source: Compiled by authors based on industrial classifications in
Input-Output Table of China, 1981 and 1987.

\section*{Price Indices}

The analysis of change in energy-use patterns over time requires that each year's input-output tables be based on the same set of prices, allowing a consistent comparison over time. We used 1981 as the base year (thus no price changes were necessary for the 1981 table) and adjusted the 1987 table to 1981 prices.

We estimated the price indices based on the real output index reported by the State Statistical Bureau of China (SSB, various years 1981-1991). Due to data limitations, we could only calculate price indices for five sectors at a very high level of aggregation-agriculture, industry, construction, transport, and commerce. We then used those five indices to convert the output into 1981 constant prices for all industries within their respective sectors. This simplified procedure undoubtedly generates some issues about the accuracy of the data, which we will try to rectify in future work.

\section*{Energy-Flow Data}

In our industrial classification scheme, there were three energy sectors: electricity, coal, and petroleum (which include natural gases). We measured all of them in terms of standard coal equivalent, based on their primary energy content and then added them to coal and petroleum.

The data on energy consumption by production sectors and categories of final demand were scarce. The primary energy flow data were available only at the highly aggregated five-sector level-agriculture, industry, construction, transportation, and commerce-and for energy sectors (SSB, 1990; 1991). \({ }^{2}\) We, therefore, had to estimate the energy consumption in specific industries based on the input-output transaction tables. We allocated energy consumption to specific sectors within agriculture and the nonenergy industrial sector based on their expenditures on the energy sectors. We believe the estimates will be reasonable, because the input-output tables were expressed in producer prices

\footnotetext{
\({ }^{2}\) The input-output tables used in the analysis were commodity-bycommodity tables; thus, they were not compatible with the standard industrial classification used in reporting industrial energy consumption.
}
and because during those years, a large percentage of the energy in China was allocated by the State under relatively uniform controlled prices.

\section*{Strengths and Limitationg of the Yodel}

The structural-decomposition analysis has at least four major strengths for use in energy analyses. First, it includes all material-production sectors of the economy and covers the entire energy production and consumption cycle. Second, unlike the traditional static input-output model, which assumes fixed technical coefficients, the structural-decomposition analysis accounts for limited changes in technologies and input substitutions. Third, the structural analysis allows us to separate the direct use or energy from the indirect use; for example, energy consumption in a radio-assembly line would be a direct use of energy, while the use of plastics in making a radio is an indirect use of energy, because energy is required to produce plastics. Fourth, the structural analysis enables us to capture not only the direct impacts of an energy-conservation measure, but also its indirect (through interindustrial purchases) and induced (through consumption effects) impacts.

We realize that our structural decomposition analysis also has some important limitations. First, the analysis assumes a linear production function or constant returns to scale, thus fails to account for energyintensity changes caused by changes in scale of production. Second, we disaggregate intermediate inputs to only 22 sectors because of lack of data. This level of disaggregation may be too high to capture some important changes in specific industries and specific production processes. Third, the structural decomposition analysis is fundamentally a top-down macroeconomic model and provides no information on how energy technologies and energy-use
practices change at the micro-level. It is often necessary, therefore, to complement the structural decomposition analysis with other types of analyses, such as econometric analyses, case studies, and institutional analyses. \({ }^{3}\) We need to take those limitations into account in using and interpreting the results of the structural decomposition analysis.

\section*{preliminary results from the structural decomposition analysis}

Tables 3 and 4 show some of the preliminary results from our structural decomposition analysis. They display, in terms of amount (Table 3) and percentage (Table 4) of energy change, the sources or underlying factors of energy-demand changes, by fuel type, in China's material-production sectors from 1981 to 1987.

Between 1981 and 1987, total energy consumption in the materialproduction sectors grew by 235 million tons of standard coal equivalent (tsce) or about 48 percent. The growth rates for electricity, coal, and petroleum \& natural gas were 56.7 percent, 57.4 percent, and 21.0 percent, respectively. This difference in the growth rates for different types of energy was, in part, a result of the Chinese government's effort to conserve ofl and to encourage the substitution of coal for oil. Because coal is inherently more difficult to utilize and has lower end-use efficiency than oil, this fuel switching should reduce energy efficiency and increase energy use in the production process.

Final-demand shifts--the rapid increase in final demand and changes in final-demand mix--was the driving force of the energy-demand growth in the 1980s. Ceteris paribus, it would increase the energy demand by 463 million

\footnotetext{
\({ }^{3}\) We are currently conducting some of these analyses.
}
tsce or 94.4 percent. This upward pressure on energy demand, however, was dampened by changes in production technology. All other things being equal, production-technology changes would reduce the energy use by 116 million tsce or 23.7 percent. The interaction of final-demand shifts and productiontechnology changes also led to a large amount of energy-saving-112 million tsce or 22.8 percent of the 1981 intermediate energy demand.

The impacts of different factors on energy use were similar across fuel types. As we can see from Table 4, with a few exceptions, the percentage changes associated with each factor were in the same direction and had a similar magnitude across fuel types.

\section*{Final-Demand Shifts}

The final-demand shift can be split into two components: (1) a change in the level of demand, where more of everything is purchased (level effect); and (2) a change in mix of what is being bought (mix effect). The level effect was the dominant factor. Of the 463 million tsce intermediate energy-use increase associated with the final-demand shift, 410 million came from the increased final-demand level, 29 million was due to the shift towards more energy-intensive final products, and 24 million is attributed to the interaction of the level and mix changes. Keeping the production technology constant, the final-demand level, mix, and interaction effect would result in, respectively, 83.6 percent, 5.9 percent, and 4.9 percent growth in intermediate energy consumption

TABLE 3
ENERGY-DEMAND CHANGE IN CHINA'S MATERIAL PRODUCTION SECTORS, 1981-1987 (1000 ton standard coal equivalent)
\begin{tabular}{|c|c|c|c|c|}
\hline Source & Primary Electricity & Coal & Petroleum \& Natural Gas & Total Primary Energy \\
\hline Final-Demand Shift & 22777.4 & 325335.3 & 114463.8 & 462576.5 \\
\hline Level Effect & 21044.0 & 282973.3 & 105572.1 & 409589.3 \\
\hline Mix Effect & 944.1 & 23072.6 & 4842.9 & 28859.7 \\
\hline Interact of the Leve1 and Mix & 789.3 & 19289.3 & 4048.8 & 24127.5 \\
\hline Production-Tech. Change & -4638.3 & -65106.9 & -46284.9 & -116030.0 \\
\hline Energy Inputs & -8750.0 & -128714.7 & -54232.3 & -191697.0 \\
\hline Nonenergy Inputs & 4111.7 & 63607.8 & 7947.4 & 75667.0 \\
\hline \multicolumn{5}{|l|}{By Sectors} \\
\hline Agricultural Sector & -96.5 & -518.2 & -2860.5 & -3475.1 \\
\hline Energy Inputs & -454.4 & -5003.4 & -4652.0 & -10109.8 \\
\hline Nonenergy Inputs & 358.0 & 4485.2 & 1791.5 & 6634.7 \\
\hline Energy Sector & -694.1 & 26332.3 & -397.3 & 25241.0 \\
\hline Energy Inputs & -824.7 & 24334.6 & -448.7 & 23061.2 \\
\hline Nonenergy Inputs & 130.6 & 1997.7 & 51.4 & 2179.8 \\
\hline \multicolumn{5}{|l|}{Nonenergy Industrial} \\
\hline Sector & -5702.8 & -113914.7 & -44270.0 & -163887.5 \\
\hline Energy Inputs & -7442.0 & -139164.5 & -47219.2 & -193825.6 \\
\hline Nonenergy Inputs & 1739.2 & 25249.8 & 2949.1 & 29938.1 \\
\hline Construction Sector & 1346.9 & 25132.6 & 2195.4 & 28674.8 \\
\hline Energy Inputs & -225.5 & -2125.2 & -320.8 & -2671.5 \\
\hline Nonenergy Inputs & 1572.4 & 27257.8 & 2516.2 & 31346.4 \\
\hline Transportation & 222.1 & -5315.0 & -1444.3 & -6537.2 \\
\hline Energy Inputs & 73.4 & -7173.3 & -1705.6 & -8805.4 \\
\hline Nonenergy Inputs & 148.7 & 1858.2 & 261.3 & 2268.2 \\
\hline Commerce & 286.1 & 3176.1 & 491.8 & 3954.0 \\
\hline Energy Inputs & 123.2 & 417.1 & 113.9 & 654.2 \\
\hline Nonenergy Inputs & 162.9 & 2759.0 & 377.9 & 3299.8 \\
\hline \multicolumn{5}{|l|}{Interact of Demand-Shift \& Production-Technology} \\
\hline Changes & -3874.6 & -65974.5 & -41688.6 & -111537.6 \\
\hline Total & 14264.6 & 194253.9 & 26490.3 & 235008.8 \\
\hline
\end{tabular}

Source: the Authors.

TABLE 4

\section*{PERCENTAGE CHANGE IN ENERGY DEMAND IN CHINA'S MATERIAL PRODUCTION SECTORS, 1981-1987}
(percent)
\begin{tabular}{|c|c|c|c|c|}
\hline Source & Primary Electricity & Coal & Petroleum \& Natural Gas & Total Primary Energy \\
\hline Final-Demand Shift & 90.5 & 96.1 & 90.6 & 94.4 \\
\hline Level Effect & 83.6 & 83.6 & 83.6 & 83.6 \\
\hline Mix Effect & 3.8 & 6.8 & 3.8 & 5.9 \\
\hline Interaction of the Level and Mix & 3.1 & 5.7 & 3.2 & 4.9 \\
\hline Production-Tech Change & -18.4 & -19.2 & -36.7 & -23.7 \\
\hline Energy Inputs & -34.8 & -38.0 & -42.9 & -39.1 \\
\hline Nonenergy Inputs & 16.3 & 18.8 & 6.3 & 15.4 \\
\hline \multicolumn{5}{|l|}{By Sectors} \\
\hline Agriculture Sector & -0.4 & -0.2 & -2.3 & -0.7 \\
\hline Energy Inputs & -1.8 & -1.5 & -3.7 & -2.1 \\
\hline Nonenergy Inputs & 1.4 & 1.3 & 1.4 & 1.4 \\
\hline Energy Sector & -2.8 & 7.8 & -0.3 & 5.2 \\
\hline Energy Inputs & -3. 3 & 7.2 & -0.4 & 4.7 \\
\hline Nonenergy Inputs & 0.5 & 0.6 & 0.0 & 0.4 \\
\hline Nonenergy Industrial & -22.7 & -33.7 & -35.1 & -33.5 \\
\hline Sector & & & & \\
\hline Energy Inputs & -29.6 & -41.1 & -37.4 & -39.6 \\
\hline Nonenergy Inputs & 6.9 & 7.5 & 2.3 & 6.1 \\
\hline Construction Sector & 5.4 & 7.4 & 1.7 & 5.9 \\
\hline Energy Inputs & -0.9 & -0.6 & -0.3 & -0.5 \\
\hline Nonenergy Inputs & 6.2 & 8.1 & 2.0 & 6.4 \\
\hline Transportation & 0.9 & -1.6 & -1.1 & -1.3 \\
\hline Energy Inputs & 0.3 & -2.1 & -1.4 & -1.8 \\
\hline Nonenergy Inputs & 0.6 & 0.5 & 0.2 & 0.5 \\
\hline Commerce & 1.1 & 0.9 & 0.4 & 0.8 \\
\hline Energy Inputs & 0.5 & 0.1 & 0.1 & 0.1 \\
\hline Nonenergy Inputs & 0.6 & 0.8 & 0.3 & 0.7 \\
\hline \multicolumn{5}{|l|}{Interact of Demand-Shift \& Production-Technology} \\
\hline Changes & -15.4 & -19.5 & -33.0 & -22.8 \\
\hline Total & 56.7 & 57.4 & 21.0 & 48.0 \\
\hline
\end{tabular}

Source: the Authors.
Note: Each percentage in the table represents a change as the percent of the energy demand within the material-production sectors in 1981.

TABLE 5
FINAL-DEMAND LEVEL AND MIX IN 1981 AND 1987
(Million 1981 RMB)
\begin{tabular}{|c|c|c|c|c|c|c|}
\hline Products & \multicolumn{2}{|l|}{1981} & \multicolumn{2}{|l|}{1987} & \multicolumn{2}{|l|}{Change} \\
\hline Agriculture & 100327.4 & 23.1 & 178979.1 & 22.4 & 78651.7 & -0.7 \\
\hline Energy & 12847.8 & 3.0 & 20287.0 & 2.5 & 7439.2 & -0.4 \\
\hline \multicolumn{7}{|l|}{Other Industrial} \\
\hline Products & 205899.0 & 47.3 & 381202.1 & 47.7 & 175303.1 & 0.4 \\
\hline Construction & 72923.0 & 16.8 & 167405.4 & 21.0 & 94482.4 & 4.2 \\
\hline Transport & 8658.2 & 2.0 & 19998.2 & 2.5 & 11340.1 & 0.5 \\
\hline Commerce & 34511.0 & 7.9 & 31105.1 & 3.9 & -3405.9 & -4.0 \\
\hline Total & 435166.3 & 100.0 & 798977.0 & 100.0 & 363810.7 & 0.0 \\
\hline
\end{tabular}

Source: Calculated by the authors based on China Input-Output Table, 1981 and 1987.

The dominance of the level effect becomes clearer and less abstract when we look at specific products purchased by final users. As shown in Table 5, China's final demand (in 1981 constant prices) increased by 84 percent from 435 billion RMB in 1981 to almost 800 billion RMB in 1987. The increase was across the board with the only exception being spending on commodity trade, which decreased, in real terms, by about 3 billion RMB. The overall spending patterns were similar for the two years--about 20 percent in agricultural goods, almost half on energy and other industrial products, 20 percent on construction, and the remaining 10 percent on transportation, communication, and commerce.

There was, however, about a 4 percent shift from the less energyintensive commerce sector to the more energy-intensive construction sector,
exerting an upward pressure on energy use. " This shift was primarily due to a rapid growth in investment. China experienced a big boom in infrastructure building (e.g., roads and bridges), housing construction (both residential and office spaces), and production-capacity expansion in the 1980s. Between 1981 and 1987, gross investment grew by 117 percent from 152 billion RMB to 329 billion RMB, much higher than the growth rate of final demand as a whole, which was 83 percent. This rapid growth in investment appears to "crowd out" some of the spending on commodity trade.

The interaction of the final-demand level and mix change increased intermediate energy use by 24 million tsce or 4.9 percent. This is because a more than disproportional amount of the demand increases was in energyintensive investment goods at the expense of commodity trade, which has low energy intensity.

\section*{Production-Technology Change}

The increased energy use associated with a final-demand shift was offset by energy savings resulting from changes in production technology. Holding the effect of changes in final demand constant, production-technology changes from 1981 to 1987 reduced energy use by 116 million tsce or about 23.7 percent of the 1981 total intermediate energy consumption. All of these energy savings were caused by an improvement in energy efficiency--the reduction in direct energy requirements--which would reduce energy use by 192 milifon tsce or 39.1 percent. The changes in nonenergy inputs, on the other hand,

\footnotetext{
4 In 1981, the total energy requirement per unit of final output was 1763.9 gsce/RMB for construction compared with 518.4 gsce/RMB for commerce sector. The differences came mainly from the uses of nonenergy inputs--construction sector use large quantity of energy-intensive materials, such as steel and cement.
}
increased energy use by 76 million tsce or 15.4 percent. China's businesses, on average, used more energy-intensive inputs, such as metallurgy, chemicals, and building materials, in 1987 than in 1981.

The changes in nonenergy input have important energy effects because in China, the direct use of energy inputs in production represent less than 10 percent of all inputs. A large percentage of the energy requirements of providing final products comes indirectly from the remaining 90 percent of the inputs, which require a significant amount of energy to produce. In the construction sector, for example, the direct energy use in the sector was only 83 gsce per RMB of output in 1981 , but 1680 gsce of energy were indirectly used because the construction materials, such as steel, glass, and cement, embody a lot of energy. Changes in the nonenergy inputs (e.g., material substitution), therefore, have an important energy consequence.

In terms of energy types, about 56 percent of the energy saving from 1981 to 1987 due to production-technology changes was in the form of coal, 40 percent in oil and natural gas, and the other 4 percent in the form of primary electricity. The contribution of oil and natural gas was disproportionally large given that it accounted for only about 20 percent of the total primary energy consumption in both 1981 and 1987. As shown in Table 4, the rate of energy-use reduction was 37 percent for oil and natural gas, about twice of that for coal and primary electricity. The high oil-saving rate was primarily the result of China's energy policy, which encouraged fuel switching from oil to abundant coal.

Tables 4 and 5 also display how the changes in energy use due to production-technology changes are distributed among different sectors of the economy. The nonenergy industrial sector accounted for most of the energy
saving. All other things being equal, its production-technology changes would save 164 million tsce energy or 33.5 percent of the 1981 total intermediate energy consumption. Furthermore, through interindustry input-output linkages, the energy-efficiency improvement of the industrial sector will be multiplied across the economy by reducing the indirect energy requirements of those sectors who use the industry's product as inputs. \({ }^{5}\) A large percentage of total energy requirements of the farming sector, for example, came from the use of chemical fertilizers. Thus, higher energy efficiency in chemicals industry not only reduces its own energy intensity but also the intensity of the farming sector. The multiplier effect is especially important for energyintensive basic materials industries, such as chemicals, metallurgy, and the building materials industry.

The rest of the energy savings came from technological changes in transportation (7 million tsce) and agriculture ( 3 million tsce). In the construction sector, the drop in energy use from the reduction in direct energy inputs was more than offset by energy-use increases from changes in nonenergy inputs. In the energy and commerce sectors, changes in both energy and nonenergy inputs resulted in higher energy use.

\footnotetext{
5 In engineering, this is called a process analysis (Miller and Blair, 1986). Analysts first identify a target product and then list the goods the goods and services directly required to deliver the product. These inputs to the target production process include energy (direct energy) and nonenergy inputs. The nonenergy inputs are then analyzed to determine the inputs to their production processes, which again include some energy and nonenergy goods and services. The process continues until analysts trace inputs back to primary resources. The first round of energy inputs is the direct energy requirement; subsequent rounds of energy inputs comprise the indirect energy requirement; and the sum of these two is the total energy requirement (Miller and Blair, 1986).
}

\section*{Interaction of the Demand Shifts and Technology Changes}

The interactive effect measures the energy impacts resulting from the simultaneous changes in final demand and production technology. It is often difficult to interpret, and different analysts treat it differently. Some analysts treat it as a separate variable and report its value (OTA, 1991; Casler and Hannon, 1989; Roop, 1987), some allocate it equally among the other factors of change (Feldman et al., 1987), while others ignore the interaction term altogether in interpreting the results of the analysis (Wolff, 1985).

Mathematically, the interactive factor in the structural decomposition analysis emerges from the basic algebra of differential equations. It adjusts the energy impact of production-technology changes to changes in the output level and mix. Ceteris paribus, the effect of production-technology changes will be larger the greater the output produced using the changed technology. In a hypothetical situation where no output was produced, the impact of technological changes on energy use would be zero because the technology had not been used at all. Similarly, the role of technological change would increase (or decrease) if the final-product users increase (or reduce) their spending on the products that have experienced the most technological changes.

Between 1981 and 1987, the interaction of final-demand shifts and production-technology changes reduces China's intermediate energy use by 112 million tsce or 22.8 percent. The energy-saving effect from the technological changes was enhanced by the higher demand level, which triggers enterprises to produce higher level of output and by the shift in spending pattern towards more energy-intensive products.

\section*{CONCLUSION}

Our structural decomposition analysis of energy-use changes in China's material production sectors shows that China's energy saving from 1981 to 1987 was caused primarily by changes in how to produce (production-technology changes) rather than changes in what to consume (final-demand shifts). The driving force of energy-intensity decline was an energy-efficiency improvement--the reduction in direct energy input coefficients in most production sectors--which was multiplied across the entire economy through interindustry input-output linkages. Because of the data constraints and the preliminary nature of the model specification, these results should be viewed as preliminary.

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A disaggregated econometric model for
the Federal Republic of Germany to
evaluate economic effects of
environmental policy *)
by Joachim Frohn

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*) To a great extent, this is a condensed English version of J. Frohn, R. Friedmann, M. Laker: "Ein disaggregiertes ökonometrisches Modell für die Bundesrepublik Deutschland zur Erfassung ökonomischer Wirkungen umweltpolitischer Maßnahmen", Texte des Umweltbundesamtes, 1989.

\section*{1. Introduction}

The political discussion is very much concerned with the question whether measures of environmental policy will mainly cause negative economic effects (for instance: reductions of employment because of increasing costs and prices; or crowdingout effects of productive investment because of enforced environmental investment) or positive economic effects (for instance: because of additional demand and possible development of new products). In most cases a specific environmental action will have both effects. Therefore it is necessary to try to evaluate the economic net effect of such measures.

For the Federal Republic of Germany there have been some empirical studies to find out about the economic effects of environmental measures \({ }^{1)}\). The main papers are due to Meissner/ Hödl (1977, 1982) and Sprenger, who tried to describe the economic reality of environmental policy. Unfortunately these authors could base their empirical studies only on a very limited data basis (input-output-tables of the years of 1958 and 1970), so that especially the derived effects of environmental measures over time could be taken into account only to a very limited extent. Furthermore it was not possible to evaluate positive and negative effects on the employment simultaneously.

In the study \({ }^{2)}\) which is described below it was the intention to overcome the mentioned difficulties of the previous studies and to make intensive use of econometrics: An econometric model was specified on the basis of a time-series of input-outputtables which allows a simultaneous evaluation of positive and negative effects.
1) C.G. Herwig, Dipper (1977), Meißner, Hödl (1977, 1982), Sprenger (1979), Sprenger, Knödgen (1983), Ullmann, Zimmermann (1982).
2) The project was strongly supported by Umweltbundesamt Berlin and Statistisches Bundesamt Wiesbaden.

It should be stressed that the main purpose was not to specify a complete environmental model but to construct an 'econometric instrument' to help to find out about the effects of environmental policies in the economic system of the Federal Republic of Germany.

As environmental measures normally will influence different parts of the economy it was necessary to specify a disaggregated econometric model. This was done on the basis of yearly input-output-tables for fifteen sectors of the German economy for 1970 to 1983. In order to take into account changes of the structure of the intermediate inputs because of technological changes or price developments, the input-coefficients are not assumed to be constant but were explained in the model. Furthermore, private consumption and private investment (except for environmental investment) are also assumed to be endogenous.

A main purpose of the study was to make use of the model for simulations of alternative basic environmental measures in order to show their effects on the economic variables according to the specified model.

In \({ }^{R}\) this context an important remark is necessary: One should bear in mind that, of course, the main purpose of environmental measures is the improvement of the environment. Therefore, the success of such measures should be evaluated in the first place with reference to the'resulting changes in the environment; the economic effects have to be classified as side-effects, and therefore the decision whether or not to take up a specific environmental action can not be based solely on the economic effects.

The paper is organized as follows: In section 2 the general concept of the model will be described. In the following paragraphs 3, 4, 5 and 6 the different parts of the model: final demand, production, prices, and income are discussed and the main estimation results are documented. In the conclusion some results of the first simulation experiments are given. But before one can start with the description of the model there should be a short discussion of the chances and limitations of such models.

As the quality of the environment normally has to be regarded as a public good, the protection and/or the improvement of the environment requires political actions by the government. In almost all cases such actions will have direct and indirect effects in different areas of the economy. Let us use as an example a legal act that will force the owners of power stations to increase the environmental standards of their machinery in order to improve the quality of the air in the neighbourhood.

In this case we have several direct effects which will have impacts on the economy within a rather short period of time: The volume and the structure of environmental investment, i.e. one component of final demand, will change; the costs connected with the purchase of the new investment goods may lead to price increases; for the operation of the new machinery the companies may need additional intermediate inputs and perhaps also additional employment. But there are also effects which will only occur after some time: There are, first of all, the indirect effects which are derived from the immediate actions of the companies: Changes in the structure and the volume of investment will cause changes in the production and will have effects on the prices of intermediate goods and the production factors and therefore also an income. This will lead to an additional change in final demand. Furthermore, the change of the price of the final and intermediate good "energy" will cause changes in final and intermediate demand for this good. This in turn will again have effects, for instance other output prices may change in reaction. The demand for new environmental goods my cause innovations, not only in goods but also in technologies. And after some time there should be an environmental effect which may cause an improvement of the health standard and therefore may cause a decrease in costs of medical care.

It is obvious that it will be very difficult to incorporate the whole set of chains of causes and consequences. Above all it almost always will be impossible to include the transformation of the legal act into economic categories. One needs information
from experts in order to be able to get an idea about the initial economic impulse. So it is quite clear, that an econometric model can only help to evaluate the derived effects which will be caused by the initial action. One can regard that as a limitation of the applicability of such a model. But on the other hand, because of the complicated structure of an interdependent economic system, without such a model one will not be able to get an understanding of the derived effects and the economic consequences of such political actions.

Of course, all possible derived effects cannot be incorporated either: As an econometric model usually can take into account only quantitative impulses, qualitative changes (for instance in the behaviour of consumers) cannot be endogenized in the model. And this is true for some quantitative effects, too: For instance, in the model discussed below we were not able to estimate the average percentage to which the entrepreneurs were able to increase their output-prices because of the enforcement of environmental actions by the government. So for simulation purposes this parameter had to be set exogenously. A second example is the incorporation of possible crowding-outeffects caused by environmental investment: An increase in environmental investment may cause a decrease in "productive" investment because of financial restrictions; furthermore in a situation close to full employment the enforced environmental activity may withdraw production factors from other areas. It was tried to include the first kind of effects in the model \({ }^{11}\); but it was not possible - except for one equation - to validate this part of the model empirically. The second type of crowding-out-effects had not been of great importance during the estimation period (1970 up to 1985), as during this period the degree of utilization was not close to 100 \%.

It has to be mentioned, that furthermore innovation and environmental effects had not been taken into account as these effects are rather difficult to evaluate; and the main intention of the study was an analysis of short term or at the most mid-term effects of environmental measures.
1) See Frohn, Friedmann, Laker (1989), p.39, ff.
2. The model

\subsection*{2.1. The general concept of the model and some remarks on \\ the specification of the model}

As already mentioned the main purpose of the project was to . analyse how an environmental impulse is carried through the economic system. This impulse has to be transformed into changes of the respective variables of the system (for instance environmental investment, other environmental expenditures, governmental expenditures, taxes, etc.) on the basis of outside information. The resulting effects of this impulse originate from the interrelations between production, the input-structure, employment, the price system and final demand. Therefore the main part of the model consists. of equations of an input-output-model, which is based on yearly input-output-tables of the economy of the Federal Republic of Germany, disaggregated into fifteen sectors. Investment is divided into environmental investment and "productive" investment; depreciation caused by environmental investment is included as special environmental costs in the general costs of the respective sector. Two components of final demand: productive investment and private consumption were regarded as endogenous variables, all the other components (environmental investment, inventories, consumption and investment of the government, exports) are exogenous. This is also true for wages, interest rates and the import prices. The input-coefficients are assumed to be variable in order to be able to take into account substitution based on price changes. In the analysis there is no separation of home and foreign products, i.e. for instance total demand for specific consumption goods (produced in Germany or in foreign countries) is explained in one euqation. Of course, the model cf production, which is the basis for the estimation of the effects on employment, refers to home production.

Some short remarks on the data \({ }^{11}\) : The input-output-tables are produced by the Statistisches Bundesamt on a yearly basis from

\footnotetext{
1) All data used in the analysis are documented in Frohn, Friedmann, Laker (1988).
}

1970 to 1983 in nominal prices and real prices (basis: 1976) \({ }^{1}\). The fifteen sectors of the German economy are the following:
1. Agricultural sector
2. Energy and water
3. Mining
4. Chemical products
5. Mineral products
6. Plastics, rubber, building materials
7. Steel, forging, hardware, metal goods
8. Machinery, computers, vehicles
9. Electric engineering, precision engineering
10. Wood, paper and board manufactures, leather, textiles
11. Food and beverages
12. Construction
13. Trade services, traffic, mail
14. Additional market-price services
15. Non-market-price services.

Time-series for environmental capital goods and the respective depreciation for private and public environmental investment and also for other environmental expenditures in the needed disaggregation are also provided by Statistisches Bundesamt (Ryll, Schäfer (1986), Schäfer (1986)). All other data come from publications of Statistisches Bundesamt (Konten- und Standardtabellen der Volkswirtschaftlichen Gesamtrechnung) and of the Bundesbank.

As far as the specification and estimation of the equations of the model is concerned the following procedure was applied: All estimations are based on yearly data from 1970 up to 1983 (in some cases up to 1985). As the model is of a recursive structure \({ }^{2)}\), all equations were estimated by ordinary least
1) Stahmer (1986).
2) The structure of the model was not determined a priori. As the outcome of the specification analysis was an "almost recursive" model, slight changes were incorporated in order to have a complete recursive structure (these changes will be mentioned in the following). The reason for preferring a recursive model is that in a simulation the derived effects of an impulse can be followed much more easily than in an interdependent model.
squares. The main criterion for the selection of a specific specification was - besides the fulfillment of economic restrictions on the coefficients - the predictive quality of the respective equation. For this purpose the predictive performance of the equations was tested in a dynamic ex-postsimulation for the years 1982 and 1983 (or 1984 and 1985).

It has to be stressed, that the time-series are very short; this, of course, has an obvious effect on the reliability of the results.

The model consists of 315 linear equations, the parameters of which had to be estimated, and identities.

\subsection*{3.1. The components of final demand}

In an input-output-model total production (home production and imported goods) can be determined via final demand. The components of final demand are:
Private demand at home, private investment for construction and machinery, investment on inventories, public consumption, public investment, exports.
According to the disaggregation of the input-output-tables used in this study final demand is disaggregted into fifteen sectors.

As already mentioned above, in this study the components "private consumption" and "private productive investment" are determined via econometric behavioural equations. The other components are concerned to be exogenous.

The specification and estimation of the econometric model for private demand for consumption is described in 3.2, the model for the determination of investment in 3.3.

\subsection*{3.2. Private consumption}

\subsection*{3.2.1. Introduction}

In order to explain private demand within the concept of input-output-tables one needs:
- an explanation of total private demand for consumption goods, and
- a disaggregation of consumption demand according to the fifteen sectors of the input-output-tables as production sectors.

Contrary to other disaggregated models for the Federal Republic of Germany (c.f. Kiy (1984), Schumann (1984)) where the supply of goods and services for final consumption is explained directly for each of the sectors of the input-output-table, in our study we followed a proposal by Preston (1972) (c.f. also Hansen Westphal (1983)). According to this approach expenditures for private consumption are explained within different consumption categories (for instance: expenditure for food, expenditure for rents, expenditure for textiles and shoes, and so on). So, "normal" consumption functions within the different consumption categories could be estimated. Of course, after approximating the expenditures in the different consumption categories, there is the necessity to break up these expenditures to the supplying sectors. For this purpose one obviously needs a bridge-matrix, linking private consumption expenditures within the consumption categories ( \(1, \ldots ., m\) ) with the sectoral suppliesaccording to the column of the final demand for private consumption in the input-output-table:
\[
\begin{align*}
& {\left[\begin{array}{l}
c_{1} \\
\vdots \\
\vdots \\
C_{15}
\end{array}\right]=\left[\begin{array}{lll}
Y_{11} & \cdots & r_{1, m} \\
\vdots & & \vdots \\
\vdots & & \\
Y_{15,1} & \cdots & r_{15, m}
\end{array}\right]\left[\begin{array}{l}
A_{1} \\
\vdots \\
\vdots \\
A_{m}
\end{array}\right] \text {. }}  \tag{3.2.1}\\
& \text { with } a_{j}: \text { consumption expenditures in category } j \\
& C_{i}: \text { supplied goods and services for consumption }
\end{align*}
\]

The coefficient \(\gamma_{i j}\) indicates what part of the consumption function in category \(j\) is supplied by sector \(i\); therefore we have the restriction
\[
\sum_{i=1}^{15} \gamma_{i j}=1
\]

The Statistisches Bundesamt has provided a bridge-matrix only for one year (1980). In section 3.2.4 it will be described how a series of bridge-matrices was constructed.

In 3.2 .3 the specification and estimation of a demand system for fractions of consumption expenditure for seven different consumption categories will be explained. In the next section 3.2.2. a macroeconomic consumption function will be specified.

\subsection*{3.2.2. The macroeconomic consumption function}

In the macroeconomic consumption function total consumption of the private households will be explained; this variable is different from a variable private internal demand as used in the input-output-table because it does not take into account consumption of private non-profit-orgnaizations. This position is considered as an exogenous variable. As the basis for the the specification of the macroeconomic consumption function the revised data of the national accounts of the Statistisches Bundesamt were used. The available input-output-tables up to 1983 are based on unrevised data and had to be adjusted (see Frohn, Friedmann, Laker (1989), p. 30 ff.).

According to the results of the specification analysis the following macroeconomic consumption function was chosen:
\[
(3.2 .2) \quad C_{t}=a_{0}+a_{1} Y_{t-1}^{V}+a_{2} \Delta P_{t}^{C}
\]
with \(Y^{V}=\) disposable income,
\(\Delta P^{C}=\) first difference of the price index for private demand

The estimation of this equation, which results in a very good approximation and prediction of macroeconomic consumption, leads to the following results \({ }^{1)}\) :
\[
\begin{gathered}
1970-85: \quad \hat{C}_{t}=42410.3+0.8540 Y_{t-1}^{V}-224877.2 \Delta P_{t}^{C} \\
(4.25)(-1.16) \\
R^{2}=0.9985 ; \quad D W=1.4767
\end{gathered}
\]

\subsection*{3.2.3. The structure of consumption according to consumption categories}

The following categories of consumption were taken into account:

Al: expenditures for food
A2: rents for houses and appartments
A3: energy
A4: expenditures for cars
A5: expenditures for traffic and information (except for cars)
A6: textiles and shoes
A7: health, hygienic and cultural expenditures; further goods and services.

In order to explain the distribution of the consumption budget of \(a\) household to the seven different categories one can use two different approaches: One can explain consumption expenditures in six categories and determine the expenditures in the leftover category as a residual. The disadvantage of this approach is quite obvious: there is no explicit explanation for the development of the expenditures in the leftover category. Therefore, in this
1) In brackets the \(t\)-values are indicated; \(R^{2}\) states the value of the coefficient of determation, \(D W\) the value of the Durbin-Watson-statistics.
study an alternative apprcach was chosen: A system of demand equations for all seven c-wegories was specified and the addingup restriction (i.e. the su: of the Eractions of consumption expenditures should add up to one) was explicitly imposed via restrictions on the coefficients of the explanatory variables.

The specification of this demand system follows the lines of the almost ideal demand system proposed by Deaton and müllbauer (1980). As this system has been described in detail in the above mentioned publication and also for our purpose in Frohn, Friedmann, Laker (1989, p.21, ff.), here only the final equation for the respective fractions of consumption expenditure is given:
\[
\begin{equation*}
w_{i}=\alpha_{i}+\sum_{i} \gamma_{i j} \log p_{j}+\beta_{i} \log \left(C / \bar{P}^{*}\right) \tag{3.2.3}
\end{equation*}
\]
with \(w_{i}\) : fractions of consumption expenditure in categy \(i\),
\(p_{j}\) : price of category \(j, C / \bar{p}^{*}\)
\(C / \bar{P}^{\star}\) : real total consumption expenditure, with \(\bar{P}^{*}\) defined as \(\bar{P}^{\star}={\underset{i}{i}}^{p_{i}} \mathbf{W}_{i}\)

Equation (3.2.3) has been used for estimation and the restrictions of homogeneity and symmetry were tested. Furthermore the inclusion of additional explanatory variables (for instance the size of households) was considered (obviously there is not much room for further variables because of the short time-series). Because of the results of the specification analysis it was decided not to introduce further explanatory variables.

It should be noted that in all seven equations for the respective fractions of consumption expenditures there are the same explanatory variables; this means, that OLS-estimations are efficient and the adding-up restriction will be fulfilled automatically.

As the predictive performance of the system was improved by taking into account the homogeneity restriction, this restriction was imposed. The symmetry restrictions, however, were not validated by the results and therefore not imposed.

The estimation results for the seven equations of the almost. ideal demand system within the model are given in table 2.1 (estimation period: 1969-1985).

Table 2.1 shows that the influence of \(\ln C\) (i.e. the .'income variable'), is negative for the first three categories, i.e. the expenditures for food, rents and energy can be regarded as "necessary goods".

The coefficients of the income variable for all seven equations add up to 0 : this is also true for the coefficients of the respective price variables, while the absolute terms of the estimated equations add up to 100 (\%).

The approximation of the observed fractions is good, the coefficient of determination in all cases is higher than 0.9. The following figures show the approximation for 1969 to 1983 and the prediction for 1984 and 1985 in comparison with the observed data. The predictive performance is regarded to be satisfactory.

With the explanation of the fractions of consumption expenditures, the nominal expenditures in the seven consumption categories can be determined by multiplying the fractions with macroeconomic consumption.
\begin{tabular}{|c|c|c|c|c|c|c|c|c|c|}
\hline onst. & \(\mathrm{InP}_{17}\) & \(\mathrm{lnP}_{27}\) & \(\mathrm{lnP}_{37}\) & \(\operatorname{lnP}_{47}\) & \(1 \mathrm{n} \mathrm{P}_{57}\) & \(\mathrm{lnP}_{67}\) & Inc & \(\mathrm{R}^{2}\) & D \\
\hline \[
\begin{aligned}
& 90.10 \\
& 12.11
\end{aligned}
\] & \[
\begin{gathered}
7.45 \\
(1.86)
\end{gathered}
\] & \[
\begin{gathered}
3.48 \\
(0.42)
\end{gathered}
\] & \[
\begin{gathered}
2.13 \\
(2.03)
\end{gathered}
\] & \[
\begin{aligned}
& -13.50 \\
& (-2.95)
\end{aligned}
\] & \[
\begin{gathered}
-8.33 \\
(-3.50)
\end{gathered}
\] & \[
\begin{gathered}
6.62 \\
(0.68)
\end{gathered}
\] & \[
\begin{aligned}
& -12.16 \\
& (-10.60)
\end{aligned}
\] & 0.9970 & 1. \\
\hline \[
\begin{aligned}
& 71.50 \\
& 5.331
\end{aligned}
\] & \[
\begin{gathered}
-4.32 \\
(-1.26)
\end{gathered}
\] & \[
\begin{gathered}
8.66 \\
(1.21)
\end{gathered}
\] & \[
\begin{gathered}
1.42 \\
(1.58)
\end{gathered}
\] & \[
\begin{aligned}
& 20.97 \\
& (5.33)
\end{aligned}
\] & \[
\begin{gathered}
2.23 \\
(1.09)
\end{gathered}
\] & \[
\begin{aligned}
& 12.68 \\
& (1.52)
\end{aligned}
\] & \[
\begin{gathered}
-4.25 \\
(-4.30)
\end{gathered}
\] & 0.9903 & 2. \\
\hline \[
\begin{aligned}
& 25.86 \\
& 3.56)
\end{aligned}
\] & \[
\begin{gathered}
-6.25 \\
(-3.37)
\end{gathered}
\] & \[
\begin{aligned}
& 16.19 \\
& (4.20)
\end{aligned}
\] & \[
\begin{gathered}
4.65 \\
(9.55)
\end{gathered}
\] & \[
\begin{gathered}
-0.79 \\
(-0.37)
\end{gathered}
\] & \[
\begin{gathered}
-3.80 \\
(-3.44)
\end{gathered}
\] & \[
\begin{gathered}
8.60 \\
(1.90)
\end{gathered}
\] & \[
\begin{gathered}
-1.50 \\
(-2.80)
\end{gathered}
\] & 0.9964 & 2 \\
\hline \[
\begin{aligned}
& 29.50 \\
& 7.931
\end{aligned}
\] & \[
\begin{aligned}
& 20.30 \\
& (4.86)
\end{aligned}
\] & \[
\begin{aligned}
& -23.25 \\
& (-2.68)
\end{aligned}
\] & \[
\begin{gathered}
-0.37 \\
(-0.34)
\end{gathered}
\] & \[
\begin{aligned}
& 11.07 \\
& (2.31)
\end{aligned}
\] & \[
\begin{gathered}
-8.38 \\
(-3.37)
\end{gathered}
\] & \[
\begin{aligned}
& -24.51 \\
& (-2.41)
\end{aligned}
\] & \[
\begin{gathered}
9.81 \\
(8.15)
\end{gathered}
\] & 0.9344 & 3. \\
\hline \[
\begin{array}{r}
48.43 \\
.8 .50)
\end{array}
\] & \[
\begin{gathered}
3.88 \\
(2.66)
\end{gathered}
\] & \[
\begin{aligned}
& -12.72 \\
& (-4.20)
\end{aligned}
\] & \[
\begin{gathered}
-1.40 \\
(-3.67)
\end{gathered}
\] & \[
\begin{gathered}
2.47 \\
(1.48)
\end{gathered}
\] & \[
\begin{gathered}
3.95 \\
(4.56)
\end{gathered}
\] & \[
\begin{gathered}
-5.53 \\
(-1.56)
\end{gathered}
\] & \[
\begin{gathered}
4.38 \\
(10.43)
\end{gathered}
\] & 0.9885 & 2. \\
\hline \[
\begin{aligned}
& -5.72 \\
& -0.521
\end{aligned}
\] & \[
\begin{aligned}
& -10.57 \\
& (-3.74)
\end{aligned}
\] & \[
\begin{gathered}
5.65 \\
(0.96)
\end{gathered}
\] & \[
\begin{gathered}
-2.85 \\
(-3.84)
\end{gathered}
\] & \[
\begin{aligned}
& -19.07 \\
& (-5.88)
\end{aligned}
\] & \[
\begin{gathered}
0.47 \\
(0.28)
\end{gathered}
\] & \[
\begin{aligned}
& 6.89 \\
& (1.0)
\end{aligned}
\] & \[
\begin{gathered}
1.88 \\
(2.30)
\end{gathered}
\] & 0.9896 & \\
\hline \[
\begin{aligned}
& -3.93 \\
& -0.18)
\end{aligned}
\] & \[
\begin{aligned}
& -10.48 \\
& (-1.93)
\end{aligned}
\] & \[
\begin{gathered}
1.99 \\
(6.18)
\end{gathered}
\] & \[
\begin{aligned}
& -3.57 \\
& (-2.50)
\end{aligned}
\] & \[
\begin{aligned}
& -1.15 \\
& (-0.19)
\end{aligned}
\] & \[
\begin{aligned}
& 13.85 \\
& (4.28)
\end{aligned}
\] & \[
\begin{gathered}
-4.75 \\
(-0.36)
\end{gathered}
\] & \[
\begin{gathered}
1.83 \\
(1.17)
\end{gathered}
\] & 0.9324 & 2. \\
\hline \multicolumn{10}{|l|}{Table 2.1: Estimation results for the parameters of the equations for the fractions of consumption expenditure
\[
A_{i} \quad(i=1, \ldots, 7), \text { with } \ln p_{j}=\ln \left(p_{i} / p_{j}\right), \ln C=\ln c_{t}^{\text {real }}
\]} \\
\hline
\end{tabular}


\(\begin{array}{llllll}69 & 72 & 75 & 78 & 81 & 84\end{array}\)
\(\begin{array}{llllll}69 & 72 & 75 & 78 & 81 & 84\end{array}\)


\(\begin{array}{llllll}69 & 72 & 75 & 78 & 81 & 84\end{array}\)
\(\begin{array}{llllll}69 & 72 & 75 & 78 & 81 & 84\end{array}\)

\section*{ \\ \(\begin{array}{llllll}69 & 72 & 75 & 78 & 81 & 84\end{array}\) \\ }


Estimation and prediction of
fractions of consumption expenditure (in \%)

\subsection*{3.2.4. Determination of the goods and services produced by the sectors for consumption}

As mentioned above, one needs a series of bridge-matrices in order to calculate the supplied goods and services of the fifteen sectors in connection with the consumption expenditures in the seven consumption categories. Unfortunately, there is only one bridge-matrix for 1980 available, which is given in table 2.2. The adequacy of a constant bridge-matrix for the whole estimation period from 1970 to 1983 on the basis of the 1980-matrix was tested by comparing the respective consumption demand positions calculated on the basis of the constant bridge-matrix with those observed and stated in. the yearly input-output-tables. The result was not satisfactory (c.f. Frohn, Friedmann, Laker (1989), p. 30 ff.). Therefore, it was decided to construct artificial yearly bridge-matrices (which are based on the observed expenditures in the consumption categories and the observed supplies of goods and services by the fifteen sectors!) by use of the wellknown RASprocedure in order to make sure that the results of the simulation experiments will not be effected by errors due to unreliable bridge-matrices \({ }^{1)}\).
1) For a description of the procedure used in the study c.f. Frohn, Friedmann, Laker (1989), p. 33 f.
\begin{tabular}{|c|c|}
\hline \(\omega\) &  \\
\hline \% &  \\
\hline \(\sim^{\circ}\) &  \\
\hline \(\alpha^{n}\) & ○○○ \\
\hline \({ }^{\circ}\) &  \\
\hline \(\sim^{m}\) &  \\
\hline \(\sim\) &  \\
\hline \[
\alpha^{-1}
\] &  \\
\hline  & \\
\hline
\end{tabular}
3.2.5. The relation of the consumption model to other parts of the model

The consumption model is connected with other parts of the model by the endogenous explanatory variables of the consumption equations. These variables are:
\begin{tabular}{|c|c|}
\hline \(Y^{V}\) & disposable income \\
\hline \(\Delta P_{C}\) & : first difference of the consumer price index \\
\hline \(P_{1}, \ldots, P_{15}\) & output prices of the 15 sectors according to the input-output-tables (total expenditure) \\
\hline \[
P_{1}^{K}, \ldots, P_{15}^{K}
\] & output prices of the 15 sectors according to the input-output-tables (expenditure for consumption) \\
\hline \(P_{1}^{C}, \ldots, P_{7}^{c}\) & prices for the goods and services in the consumption categories ( \(A_{1}, \ldots, A_{7}\) ) \\
\hline
\end{tabular}

The explanation of the disposable income will be discussed in section 5, the explanation of the output-prices as far as total expenditure is concerned will be dealt with in section 4.

The output-prices for the goods and services of the fifteen sectors concerning consumption expenditure are calculated by dividing nominal consumption expenditure of the sector by the respective real consumption expenditure:
(3.2.4)
\[
P_{i t}^{K}=\frac{C_{i t}^{n o m i n a l}}{C_{i t}^{\text {real }}}, \quad i=1, \ldots, 15
\]

The price indices are quite different from the output prices for total expenditure; nevertheless they can be well approximated by a simple linear regression with the respective output price for total expenditure as the only explanatory variable:
\[
\begin{equation*}
p_{i t}^{K}=\alpha_{1}+\beta_{1} p_{i t}, \quad i=1, \ldots, 15 \tag{3,2.5}
\end{equation*}
\]

The approximation and the predictive performance of these equations is satisfactory (except for one case all coefficients of determination are above 0.9). The prices for the seven consumption categories would normally be calc̣ulated via the artificial yearly bridge-matrix \(\gamma\) (c.f. 3.2.1)):
\[
\left[\begin{array}{l}
P_{1}^{c} \\
\vdots \\
\vdots \\
P_{7}^{c}
\end{array}\right]=\left[\begin{array}{lll}
r_{11} & \cdots & \cdots \\
\vdots & & r_{15,1} \\
\vdots & & \vdots \\
r_{1,7} & \cdots & r_{15,7}
\end{array}\right]\left[\begin{array}{l}
p_{1}^{K} \\
\vdots \\
\vdots \\
P_{15}^{K}
\end{array}\right]
\]

Unfortunately it is not true that the sectors are "more disaggregated" than the consumption categories: For instance, in case of expenditures for rents we have one consumption category; but the only sector that provides this service to private consumption is sector 14, which provides other services, too. As this is not only true for consumption category 2 but - to a lesser extent - for the other categories, it was decided to approximate the prices in connection with expenditure in the seven categories in the following way: According to the bridge-matrix those sectors which supply the highest part of goods and services to the respective consumption categories are explained by linear regression equations with the price indices of the main sectors as explanatory variables. As the sectoral price indices for consumption expenditure are approximated by a regression equation with a price index for total expenditure in the respective sector, the approximating equations were formulated on the basis of the price indices for total expenditure of the main sectors. So the following equations were used:
\[
\begin{aligned}
& P_{1 t}^{c}=a_{1}+b_{1} P_{11 t}+c_{1} P_{13 t}+d_{1} P_{14 t} \\
& P_{2 t}^{c}=a_{2}+b_{2} P_{14 t} \\
& P_{3 t}^{c}=a_{3}+b_{3} P_{2 t}+c_{3} P_{5 t}+d_{3} P_{13 t} \\
& P_{4 t}^{c}=a_{4}+b_{4} P_{8 t}+c_{4} P_{13 t} \\
& P_{5 t}^{c}=a_{5}+b_{5} P_{5 t}+c_{5} P_{8 t}+d_{5} P_{13 t} \\
& P_{6 t}^{c}=a_{6}+b_{6} P_{10 t}+c_{6} P_{13 t} \\
& P_{7 t}^{c}=a_{7}+b_{7} P_{9 t}+c_{7} P_{13 t}+d_{7} P_{14 t}+d_{8} P_{15 t}
\end{aligned}
\]

The approximation and predictive performance for all these equations are good; \(R^{2}\) is always larger than 0.9 .

These \(P_{i t}^{C}\) were also used for the calculation of the consumption price index in the consumption demand system (c.f. (3.2.3)). But instead of the weights \(w_{i t}\) the estimated fractions with a time-lag of \(1\left(w_{i t-1}\right)\) were used in order to keep the model recursive. This approximation is not very harmful as the fractions of consumption expenditures in the respective categories will not change strongly from year to year.

\subsection*{3.3. Investments}

\subsection*{3.3.1. Specification and estimation of investment-functions \\ for gross-investment}

Very similar to the approach in section 3.2. investment functions were specified for investing sectors (contrary to a direct determination of goods and services provided for investment in the different sectors). Therefore again the problem of "bridging" investment expenditures and the goods and services needed for the investment goods had to be solved.

The following eight investing sectors were considered (according to the available data):
1. agriculture
2. energy
3. mining
4. manufacturing industry
5. construction
6. trade and traffic
7. general services without letting apartments
8. letting apartments.

Investment functions were specified only for "productive" investment.

As was already mentioned in the introduction, productive and environmental investment can influence each other: Additional environmental investment which is enforced by law can reduce (for instance because of financial restrictions) or increase productive investment (for instance because of lowering costs if the environnental investment and productive investment planned for later periods are realized in the same period). In order to take this aspect into account, on the basis of Jorgenson's capital thaory (Jorgenson (1963), (1965)) a model was developed with productive and environmental investment as decision variables (Frohn, Friedmann, Laker (1989), p. 40, ff.).

The investment function derived from this appraoch could be validated only in the mining sector:
\[
\begin{aligned}
& \text { (3.3.1) } \\
& \begin{aligned}
I_{3 t}= & 6523.1+1747.0 t+\underset{(2.78)}{(5.90)} \begin{aligned}
&(3.53)\left(\frac{P_{3 t}^{X}}{C_{3 t}}\right)-15.48 K_{3 t-1}^{U} \\
&(-3.37)
\end{aligned}
\end{aligned} \\
& \begin{array}{ccc}
-0.81 I_{3 t-1}- & 0.41 I_{3 t-2}-0.95 I_{3 t-3} \\
(-1.99) & (-2.94) & (-3.94)
\end{array} \\
& R^{2}=0.98 ; \quad D W=2.94
\end{aligned}
\]
```

With $\mathrm{p}^{\mathrm{X}}=$ input-price-index,
$\mathrm{K}^{\mathrm{U}}=$ capital stock for environmental purposes,
$C$ = user costs of capital in the mining sector ( $i=3$ )

```
(3.3.1) shows that a reduction of productive investment will occur if the capital stock for environmental purposes is increased.

In all the other sectors the specification of the functions for gross investment was based on the usual explanatory variables, i.e. production of the respective sector, investment of previous years, and cost factors (interest rates, wages); a dependence on profits was not significant.

A different approach was only ohosen for the investment function for the sector "letting apartments": The most important explanatory variables in this case are interest rates of mortgages, the rent, and the average number of persons living in an apartment (as an indicator of changing quality demands).

In the investing sectors 2 and 6, dummy variables had to be introduced in order to include the effects of behavioural changes due to the oil-crisis.

The following table and figures show the estimation results (and predictive performance) for the investment functions for productive gross investment for 1971 up to 1983:

Agriculture, fishery:
\[
I_{1 t}=\underset{(4.52)}{11280.5-\underset{(-4.13)}{39595.2} r_{t-1}+\underset{(3.33)}{9552.5} P_{1 t-1}}
\]
\[
\begin{aligned}
&- 1567.31_{1 t-1}+ \\
&(-2.03) 932.4 t \\
&(1.65)
\end{aligned}
\]
\[
R^{2}=0.84 ; \quad D W=2.57
\]

Energy:
\[
\begin{aligned}
& I_{2 t}= \underset{(0.67)}{1790.6}+\underset{(2.98)}{0.1211} X_{2 t-1}+ \\
&(3.30)
\end{aligned}
\]
+2424.7 D7075 \(_{t}\) (3.70)
\[
R^{2}=0.76 ; \quad D W=2.91
\]

Manufacturing Industry:
\[
\begin{aligned}
& \begin{aligned}
I_{4 t}= & 15527.0+\underset{(1.18)}{(1.54)} \begin{aligned}
0.0194 & X_{4 t-1}
\end{aligned}+\underset{(2.43)}{0.6085} I_{4 t-1}
\end{aligned} \\
& -0.0416 I_{4 t-2}-164876.7 r_{t-1} \\
& \text { (-0.17) (-2.66) } \\
& R^{2}=0.88 ; \quad D W=2.09
\end{aligned}
\]

\section*{Construction:}
\[
\begin{aligned}
& I_{5 t}= 13251.4-0.07 X_{5 t-1}-50771.6 r_{t} \\
&(3.47)(-2.05) \\
&+ 1.1316 I_{5 t-1} \\
&(8.84) \\
& R^{2}=0.91 ; \quad D W=2.20
\end{aligned}
\]

Trade and traffic:
\[
\begin{aligned}
I_{6 t}= & 44958.75-82742.04 r_{t-1}+\underset{(2.57)}{ } \begin{aligned}
&(14.96) \\
&(-4.21) \\
&-6109.28 \mathrm{D} 7 \mathrm{X}_{6 t-1} \\
&(-7.43) \\
& R^{2}=0.92 ; \quad D W=2.49
\end{aligned}
\end{aligned}
\]

General services (without letting apartments):
\[
\begin{aligned}
I_{7 t}= & 28.36-223498.3 r_{t-1}+0.060 X_{7 t-1} \\
& (0.04)(-6.88) \\
& +0.5583 I_{7 t-1} \\
& (4.44) \\
& \left.R^{2}=0.98\right) \quad D W=2.27
\end{aligned}
\]

Letting apartments:
\[
\begin{aligned}
& I_{8 t}=-474443.6-428535.7 R_{t-1}^{H}+1807.9 M_{t} \\
& (-5.05)(-5.98) \\
& \text { (5.56) } \\
& -152669.5 \mathrm{PW}_{t}+0.57 \mathrm{I}_{8 t-1} \\
& \text { (5.76) } \\
& \text { (4.98) } \\
& R^{2}=0.89 ; \quad D W=2.28
\end{aligned}
\]
with
\(r_{t}\) : interest rate of bonds
\(R_{t}^{H} \quad\) : interest rate for mortgages
\(M_{t}\) : rent index for newly constructed apartments

The estimation results and the results of the simulations were regarded satisfactory.





\subsection*{3.3.2. Separation of gross-investment in machinery and in construction}

As environmental measures can effect investment in machinery and in construction in different ways it was necessary to find a way of separating investment in machinery and in construction. As an empirical analysis showed that investment in machinery can be explained very well via the investment functions for total investment, these equations were estimated anew for investment in machinery. Investment in construction can then be calculated as the difference between the estimated total investment and the estimated investment in machinery.

\subsection*{3.3.3. Determination of goods and services for investment}

As already mentioned, because of estimating investment functions for investing sectors it again was necessary to determine the amount of goods and services provided by the different sectors for the investment goods. As in case of consumption expenditure there is only information for 1980.

The two bridge-matrices for investment in machinery and in construction are given in table 3.3 and 3.4. These matrices are not completely compatible with the investment data in the investment sectors as components of final demand in the input-output-tables. For instance, the disaggregation in the bridgematrices is different from the disaggregation used in the model; and there are further differences. The procedures for solving these difficulties are described in details in Frohn, Friedmann, Laker (1989), p. 50, ff.. In order to provide yearly bridgematrices, again the RAS-procedure was applied in the same way as in case of consumption.
\begin{tabular}{|c|c|c|c|c|c|c|c|c|}
\hline \begin{tabular}{l}
Investing \\
Sector
\end{tabular} & \multirow[b]{2}{*}{1} & \multirow[b]{2}{*}{2} & \multirow[b]{2}{*}{3} & \multirow[b]{2}{*}{4} & \multirow[b]{2}{*}{5} & \multirow[b]{2}{*}{6} & \multirow[b]{2}{*}{7} & \multirow[b]{2}{*}{\(\Sigma\)} \\
\hline Producing Sector & & & & & & & & \\
\hline 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & \(\bigcirc\) \\
\hline 2 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
\hline 3 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
\hline 4 & 0 & \(\bigcirc\) & 0 & 0 & 0 & 0 & 0 & 0 \\
\hline 5 & 0 & 0 & 0 & 0 & . 0 & 0 & 0 & 0 \\
\hline 6 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & \(\bigcirc\) \\
\hline 7 & \(\bigcirc\) & 0 & 814 & 0 & 67 & 0 & 0 & 881 \\
\hline 8 & 5818 & 4359 & 30322 & 4475 & 14787 & 11576 & 2485 & 73822 \\
\hline 9 & 580 & 3431 & 8845 & 62 & 6498 & 10041 & 2048 & 31505 \\
\hline 10 & 57 & 67 & 1403 & 63 & 1155 & 2482 & 519 & 5746 \\
\hline 11 & 0 & 0 & 0 & \(\bigcirc\) & 0 & \(\bigcirc\) & 0 & 0 \\
\hline 12 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
\hline 13 & 1175 & 973 & 5686 & 550 & 1799 & 3551 & 42 & 13776 \\
\hline 14 & \(\bigcirc\) & \(\bigcirc\) & \(\bigcirc\) & 0 & \(\bigcirc\) & 0 & 0 & 0 \\
\hline 15 & \(\bigcirc\) & \(\bigcirc\) & \(\bigcirc\) & \(\bigcirc\) & \(\bigcirc\) & \(\bigcirc\) & \(\bigcirc\) & \(\bigcirc\) \\
\hline \(\Sigma\) & 7630 & 8830 & 47070 & 5150 & 24306 & 27650 & 5094 & 125730 \\
\hline Turnover Tax & 0 & 0 & 0 & 0 & 624 & 760 & 756 & 2140 \\
\hline \(\Sigma\) & 7630 & 8830 & 47070 & 5150 & 24930 & 28410 & 5850 & 127870 \\
\hline
\end{tabular}

Table 2.3: Bridge-matrix (1980) for investment in equipment in mill. DM
\begin{tabular}{|l|rrrrr|}
\hline \begin{tabular}{|l|l} 
Investing \\
Sector
\end{tabular} & \multicolumn{5}{|c|}{} \\
\hline Producing & 1 & 2 & 3 & 1 & \(\Sigma\) \\
Sector & & & & & \\
\hline 1 & 5 & 59 & 224 & 33 & 321 \\
2 & 0 & 0 & 0 & 0 & 0 \\
3 & 0 & 0 & 0 & 0 & 0 \\
4 & 0 & 0 & 0 & 0 & 0 \\
5 & 0 & 0 & 0 & 0 & 0 \\
6 & 0 & 0 & 16 & 0 & 16 \\
7 & 22 & 395 & 1179 & 3323 & 4919 \\
8 & 46 & 827 & 2844 & 6081 & 9798 \\
9 & 5 & 90 & 368 & 3563 & 4026 \\
10 & 0 & 0 & 372 & 0 & 372 \\
11 & 0 & 0 & 0 & 0 & 0 \\
12 & 1750 & 43070 & 75042 & 43550 & 163412 \\
13 & 0 & 0 & 0 & 0 & 0 \\
14 & 52 & 929 & 2775 & 6830 & 10586 \\
15 & 0 & 0 & 0 & 0 & 0 \\
\hline\(\Sigma\) & 1880 & 45370 & 82820 & 63380 & 193450 \\
Turnover Tax & 0 & 5660 & 9710 & 1290 & 16660 \\
\hline\(\Sigma\) & 1880 & 51030 & 92530 & 64670 & 210110 \\
\hline
\end{tabular}

Table 2.4: Bridge-matrix (1980) for investment in construction in mill. DM

\section*{4. The production model}

\subsection*{4.1. Introduction}

In an input-output-model the relation between the components of final demand \(f\) and the vector of gross production \(x\) is determined via the matrix \(A\) of the input-coefficients:
(4.1) \(\quad x=A \cdot x+f, \quad A=\left(a_{i j}\right), \quad a_{i j}=\frac{x_{i j}}{x_{j}}\)
(4.1) describes a linear production model with constant production coefficients. The assumption of constant input-coefficients was tested in an empirical analysis with the result that it cannot be accepted (the following four figures show the variation of four selected input coefficients). A large number of the input coefficients underwent considerable variations in time, and very often in a systematic way. Therefore it was decided to try to find a model to explain these developments.

The basic specification was derived from a production model with neoclassical production functions and the assumption of cost minimization as the entrepreneurial goal. As the input coefficients are now variable, the input-output-tables can only be regarded as consistent disaggregated pictures of economic transactions and not as an economic model in itself.

The basic theoretical model is described in details in Frohn, Friedmann, Laker (1989), p. 58 ff.. Here only the main elements shall be stated:
- It is assumed that there is a representative enterprise for each sector.
- Total production in each sector can be represented by an identical neoclassical production function.
- In the derivation the duality of production and costs is used, and it is assumed that the cost funciton of each sector can be approximated by a translog-function (c.f. Fuss (1977), Hudson/Jorgenson (1976)).

- As an approximation it was assumed that the optimization can be separated into the optimal composition of the intermediate inputs and the optimal production on the basis of the production function with this aggregate of intermediate inputs and an aggregate for the primary inputs.

According to this model, the fractions of intermediate inputs \(x_{i j}\) of total input in sector \(j: x_{j}^{V O R}\) is determined as follows:
\[
\begin{equation*}
a_{i j}^{V O R}=\delta_{i}^{j}+\sum_{k=1}^{n} \ln p_{k}+\beta_{o x}^{j} \ln x_{j}^{V O R}, i=1, \ldots, n \tag{4.2}
\end{equation*}
\]
with \(p_{k}=\) prices of intermediate inputs.

The relation of total intermediate inputs in sector \(j\) and production of sector \(j\)
\[
\left(v_{j}^{V O R}=\frac{x_{j}^{V O R}}{x_{j}}\right)
\]
is given by
(4.3) \(\quad v_{j}^{V O R}=\alpha^{j}+\gamma_{v v}^{j} \ln p_{j}^{V O R}+\gamma_{v p}^{j} \ln p_{j}^{P R I M}+\gamma_{v x}^{j} \ln X_{j}\)
\[
\begin{aligned}
\text { with } p_{j}^{V O R} & =\text { price index for intermediate inputs, } \\
p_{j}^{P R I M} & =\text { price index for primary inputs. }
\end{aligned}
\]

\subsection*{4.2. The econometric estimation of the production model}

In accordance with the information from the input-output-tables of the Statistisches Bundesamt the input-coefficients are based on the toal amount of goods and services, i.e. the input-coefficients \(a_{i j}\) are defined as relation of the supplied intermediate input \(x_{i j}\) divided by the sum of internal production of sector \(j\) plus the total amount of imported goods of the same kind of the respective sector: \(x_{j}^{I N L}+x_{j}^{G A}\). Thus the input-coefficient \(a_{i j}\) can be represented as the product of three factors:
(4.4) \(a_{i j}=a_{i j}^{V O R} \cdot v_{j}^{V O R} \cdot b_{j}\),
with
\[
\begin{aligned}
a_{i j}^{V O R}=\frac{x_{i j}}{x_{j}^{V O R}} & \text { input fraction } \\
v_{j}^{V O R}=\frac{x_{j}^{\text {VOR }}}{x_{j}^{I N L}} & \text { input-production-relation } \\
b_{j}=\frac{x_{j}^{\text {INL }}}{x_{j}^{G A}} & \begin{array}{l}
\text { fractions of internal production } \\
\text { to total amount of goods and } \\
\text { services }
\end{array}
\end{aligned}
\]

For these three multiplicative components of \(a_{i j}\) equations were specified for each sector, and estimated by use of ols.
4.2.1. The input fractions ( \(\left.a_{i j}^{V O R}\right)\)

As far as the specification of equations for the input fractions are concerned one has to take care of two important aspects:
- The sum of the input fractions for each sector has to add up to one \(\left(\sum_{i=1}^{15} a_{i j}^{V O R}=1\right)\).
- The basic equations derived from a theoretical discussion (c.f. (4.2)) cannot directly be used as the time series of input-output-tables are too short (only 14 observations).

To fulfill the adding-up-restrictions mentioned above the same approach was used as in case of the demand system for consumption, namely OLS-estimations of equations with the same explanatory variables for all fifteen input fractions of one sector.

To reduce the number of explanatory variables the fifteen sector prices were combined to three price aggregates (all prices are calculated as indices equal to the relation of the respective nominal and real positions in the input-output-tables). As the development of the prices during the observation period show rather strong multicollinearity it was possible to find three fairly homogeneous aggregates of prices. So the following price indices were used as explanatory variables in the sectors:
1. price index for manufacturing industry:
\[
\begin{aligned}
& P v_{t}=\frac{\sum_{v}^{\sum x_{i t}^{G A} p_{i t}}}{\sum_{I_{v}} x_{i t}^{G A} p_{j, 76}} \\
& I_{v}=\{4,6,7,8,9,10,11\}
\end{aligned}
\]
2. price index for mineral oil and mining:
\[
\begin{aligned}
& P M_{t}=\frac{I_{M}^{\Sigma x_{i t}^{G A} p_{i t}}}{\sum_{M}^{\sum x_{i t}^{G A}} p_{i, 76}} \\
& I_{M}=\{3,5\}
\end{aligned}
\]
3. price index for energy:
\[
P E_{t}=\frac{x_{2 t}^{G A} p_{2 t}}{x_{2 t}^{G A} p_{2,76}}
\]

These three price indices were related to the price of the receiving sector, and the logarithms of these relations (see (4.2)) were used as explanatory variables.

To take into account possible effects of technical progress ( \(\xi_{j t}\) ) alternatively trend variables or the energy input-coefficient (lagged by one period) were used. Either the total amount of inputs (again lagged by one period) or the respective inputcoefficient were used for possible effects of scale.

So the following basic equation which was used for approximating the development of the input fractions:
(4.5) \(\quad a_{i j t}^{V O R}=b_{o i j}+b_{1 i j} \cdot \ln \left(\frac{P V_{t}}{p_{j t}}\right)+b_{2 i j} \cdot \ln \left(\frac{P M_{t}}{P_{j t}}\right)\)
\[
+b_{3 i j} \cdot \ln \left(\frac{P E_{t}}{P_{j t}}\right)+b_{4 i j} \cdot E_{j t}+b_{5 i j} \cdot z_{j t}
\]
with
a) Linear trend
\(\xi_{j t}:\)
b) energy input fraction \(t-1\)
c) total input of the sector ( \(t-1\) )
\(z_{j t}:\)
d) input-coefficient of the sector

For each sector these alternatives were estimated and the final equation was chosen according to the following criteria:
\begin{tabular}{rl}
\(R^{2}\) & coefficient of determination for the period 1971 to \\
\(\bar{\sigma}^{2}:\) & the mean square error for the estimation for 1971 \\
& to 1981
\end{tabular}

In the specification analysis main emphasis was put on the predictive performance; therfore some of the equations were chosen inspite of a rather poor fit during the observation period.

In the following the estimation results and figures for approximations and predictions are given for the four inputfractions already mentioned above.
\[
\begin{aligned}
& -0.1476 \mathrm{VA}_{2 t} \\
& \text { (-4.78) } \\
& R^{2}=0.80 ; \quad D W=2.08 \\
& \bar{a}_{15,8, t}^{\mathrm{VOR}}=0.0155-0.0003 P M_{t}+0.0112 \mathrm{PV}_{t}+0.0065 \mathrm{PE}{ }_{t} \\
& \text { (1.84) (-1.26) (4.22) (6.70) } \\
& +0.3035 \mathrm{a}_{2,8, t-1}^{\mathrm{VOR}}-0.0191 \mathrm{VA}_{8 t} \\
& \text { (1.41) (-1.84) } \\
& \mathrm{R}^{2}=0.97 ; \quad \mathrm{DW}=2.77 \\
& \bar{a}_{6,9, t}^{\mathrm{VOR}}=-0.0210-0.0074 \mathrm{PM}+0.0931 \mathrm{PV} \mathrm{t}_{\mathrm{t}}-0.0086 \mathrm{PE} \mathrm{t}_{\mathrm{t}} \\
& \text { (-1.10) (-2.51) (3.29) (-1.76) } \\
& \begin{aligned}
&+ 0.1538 V A_{9 t}+ \\
&(4.02) 0.0021 t \\
&(10.3)
\end{aligned} \\
& R^{2}=0.99 ; \quad D W=2.05 \\
& \mathrm{a}_{14,13, t}^{\mathrm{VOR}}=0.3827+0.0504 \mathrm{PM}_{t}-0.3803 \mathrm{PV}_{t}+0.1022 \mathrm{PE} \mathrm{P}_{\mathrm{t}} \\
& \text { (2.39) (2.09) (-1.35) (1.68) } \\
& -2.8400 \mathrm{a}_{2,13, t-1}^{\mathrm{VOR}}+0: 4426 \mathrm{VA}_{13 t} \\
& \text { (-1.49) (0.95) } \\
& R^{2}=0.95, \quad D V=1.50
\end{aligned}
\]
with \(V A_{t}\) : input-production-relation.



\(\begin{array}{lllllll}70 & 72 & 74 & 76 & 78 & 80 & 82\end{array}\)
\(\begin{array}{lllllll}70 & 72 & 74 & 76 & 78 & 80 & 82\end{array}\)
Estimation and prediction of selected input-fractions

\subsection*{4.2.2. The input-production-relation}

The fifteen input-production-relations can be specified independently because there are no restriction combining one with the others.

According to the theoretical model, as an indicator for the prices of primary inputs of each sector the sectoral wage was chosen. In the specification this wage as well as the price for intermediary inputs were taken into account as relative prices, divided by the internal output-price. In some sectors \((2,6,8,10,12,15)\) the lacked endogenous variable was also taken into account as one explanatory variable. To represent technical progress a linear and/or a quadratic time trend was chosen. According to these considerations following equation was used as a basic specification:
\[
\begin{align*}
v_{j t}^{V O R}= & c_{o j}+c_{1 j} \cdot \frac{p_{j t}^{V O R}}{p_{j t}^{I N L}}+c_{2 j} \cdot \ln \frac{w_{j t}}{p_{j t}^{I N L}}  \tag{4.6}\\
& +c_{3 j} \cdot t+c_{4 j} \cdot t^{2}+c_{5 j} \cdot v_{j t-1}^{V O R}
\end{align*}
\]

In (4.6) \(p_{j t}^{V O R}\) indicates the price-index for the aggregate of intermediary inputs of sector \(j\).

For the four already mentioned input-production-relations the following results of the estimation were calculated:
\[
\begin{aligned}
& R^{2}=0.72 ; \quad D W=1.78
\end{aligned}
\]
\[
\begin{aligned}
\bar{v}_{9, t}^{V O R}= & 0.5226-0.0027 t \\
& (139.43)(-6.17) \\
& R^{2}=0.76 ; \quad D W=1.21 \\
\bar{v}_{13, t}^{V O R}= & 0.2846+0.0021 t \\
& (85.94) \quad(5.35) \\
& R^{2}=0.70 ; \quad D W=2.35 \\
\bar{v}_{2, t}^{V O R}= & 0.2839+0.4834 v_{2, t-1}^{V O R}+0.1805 \ln \left(\frac{p_{2, t}^{V O R}}{p_{2, t}^{I N L}}\right)-0.0068 t \\
& (2.94) \quad(2.66) \\
& R^{2}=0.94 ; \quad D W=1.60
\end{aligned}
\]

The following graphs show the approximation and the prediction according to the estimated results.


\subsection*{4.2.3. The fraction of internal production to the total \\ amount of goods and services ( \(b_{j}\) )}

In order to explain these fractions ( \(b_{j t}\) ) equations for the fraction of imported goods of the same kind (imp \({ }_{j t}=1-b_{j t}\) ) were specified.

It was assumed that the relation between the imported and internally produced goods of the same kind is mainly determined by the relation of the respective prices: \(\left(\frac{p_{j t}^{I M P}}{p_{j t}^{I N L}}\right)\).

As further explanatory variables the lagged endogenous variables and a linear trend were used. For sector 13 and 15 the best results occurred for constant relations. In the following the results of the estimation and in the figures the approximation and the prediction for sectors 8, 9, 11 and 13 are documented.
\[
\begin{align*}
\mathrm{imp}_{2, t}= & 0.0033+0.7550 \mathrm{imp}_{2, t-1} \\
& (1.21) \quad(3.80) \\
& \mathrm{R}^{2}=0.57 ; \quad \mathrm{DW}=1.17  \tag{54.55}\\
\mathrm{imp}_{13, t}= & 0.0314 \quad \begin{array}{l}
(54.55)
\end{array}
\end{align*}
\]
\[
\begin{align*}
\operatorname{imp}_{8, t}= & 0.0629+0.1225 \ln \left(\frac{p_{8 t}^{I M P}}{p_{8 t}^{I N L}}\right)+0.0070 t \\
& (11.08)(3.44)  \tag{9.74}\\
& R^{2}=0.96 ; \quad D W=1.49
\end{align*}
\]
\(\inf _{9, t}=0.0761+0.1152 \ln \left(\frac{p_{g t}^{I M P}}{p_{9 t}^{I N L}}\right)+0.0108 t\)
(12.84) (1.63)
(12.29)
\[
R^{2}=0.99 ; D W=1.67
\]


\subsection*{4.3. The input-coefficients}

On the basis of equation (4.4) one can calculate each input-coefficient as the product of the respective three relations. It is not possible to give the results for all 225 input-coefficients; the following figures show the approximations and predictions for those input-coefficients which had been used as examples already.

The results are quite satisfatory.

5. The model for the output-prices

The specification of the equations for the output-prices was based on the concept of mark-up-prices; i.e. it was assumed that the sectoral output-prices are calculated by multiplying the costs by a certain factor larger than one.

In order to be able to determine the effects of environmental expenditures on prices it was assumed that these expenditures are unproductive, i.e. that they will not increase the production of the respective sector. Under this assumption it is possible to separate an observable output-price charged to demanders of the products and a fictious output-price which is defined as the price which would have been charged if no environmental expenditures had been taken into account ("productive price"). The observable output-price is calculated as the fraction of nominal and real home production of the respective sector. The fictious productive output-price is calculated according to the following formula:
\[
\begin{equation*}
P_{i t}^{\star}=\frac{x_{i t}^{I N L . N O M}-U_{i t}^{N O M}}{x_{i t}^{I N L}} \tag{5.1}
\end{equation*}
\]
with \(U_{i t}^{N O M}=\) nominal environmental expenditures of the \(i-t h\) sector (equal to current environmental expenditures and depreciations on environmental investment; for the data see Ryll, Schäfer (1986), Frohn, Friedmann, Laker (1988)).

In order to keep the recursive structure of the model it was necessary to change the above formula for \(P_{i t}^{*}\) in the following way:
\[
\begin{equation*}
P_{i t}^{\star}=\frac{x_{i t}^{I N L \cdot N O M}}{x_{i t}^{I N L}}-\frac{U_{i t}^{N O M}}{x_{i t-1}^{I N L}} \tag{5.2}
\end{equation*}
\]

As the equation for the determination of the productive outputprice the following concept was used:
\[
\begin{equation*}
P_{i t}^{*}=\mu_{i t}\left[\sum_{j=1}^{15} a_{j i t-1}^{V O R} v_{i t-1}^{V O R} p_{j t-1}+\frac{E A_{i t-1}}{x_{i t-1}^{I N L}}\right] \tag{5.3}
\end{equation*}
\]

In (5.3) \(a_{j t-1}^{V O R} \cdot v_{i t-1}^{V O R}\) represents the relation of supplies of sector \(j\) for home production of sector i; \(E A_{i t-1}\) stands for the nominal non-profit income of sector i. So the costs consist of lagged input costs and lagged non-profit incomes related to the output of the respective sector.

In order to take into account time depending variations of the relation between these costs and the price, the mark-upcoefficient \(\mu_{i t}\) was specified as time-dependent:
(5.4) \(\mu_{i t}=\alpha_{i}+\beta_{i} \cdot t\).

Table 5.1 gibes the results for the estimation of the mark-upequations; the figures indicate the approximation of the observed prices for 1970 to 1981 and predictions for 1982 to 1983.

After the calculation of the productive output-price according to (5.3) the observable output-price can be calculated as follows:
(5.5)
\[
\bar{p}_{i t}^{I N L}=\bar{p}_{i t}^{\star}+\frac{U_{i t}^{N O M}}{x_{i t-1}^{I N L}}
\]
\begin{tabular}{|c|c|c|c|c|}
\hline Sektor & \(\alpha_{i}\) & \(\beta_{i}\) & \(\mathrm{R}^{2}\) & DW \\
\hline 1 & \[
\begin{gathered}
1.683 \\
(28.8)
\end{gathered}
\] & \[
\begin{aligned}
& -0.011 \\
& (-1.7)
\end{aligned}
\] & 0.91 & 1.00 \\
\hline 2 & \[
\begin{gathered}
1.770 \\
(50.0)
\end{gathered}
\] & \[
\begin{aligned}
& -0.019 \\
& (-5.3)
\end{aligned}
\] & 0.99 & 0.80 \\
\hline 3 & \[
\begin{aligned}
& 1.114 \\
& (19.9)^{1}
\end{aligned}
\] & \[
\begin{aligned}
& 0.015 \\
& (2.6)
\end{aligned}
\] & 0.98 & 1.41 \\
\hline 4 & \[
(24.235)
\] & \[
\begin{aligned}
& -0.010 \\
& (-1.9)
\end{aligned}
\] & 0.89 & 1.59 \\
\hline 5 & \[
\begin{aligned}
& 1.427 \\
& (6.7)^{\prime}
\end{aligned}
\] & \[
\begin{aligned}
& 0.024 \\
& (1.2)
\end{aligned}
\] & 0.91 & 1.19 \\
\hline 6 & \[
\begin{gathered}
1.302 \\
(46.8)
\end{gathered}
\] & \[
\begin{aligned}
& -0.009 \\
& (-3.1)
\end{aligned}
\] & 0.97 & 1.57 \\
\hline 7 & \[
\begin{aligned}
& \frac{1}{1.180} \\
& (27.7)
\end{aligned}
\] & \[
\begin{aligned}
& -0.015 \\
& (-3.2)
\end{aligned}
\] & 0.86 & 2.29 \\
\hline 8 & \[
\begin{aligned}
& 1.164 \\
& (99.4)
\end{aligned}
\] & \[
\begin{aligned}
& -0.000 \\
& (-0.0)
\end{aligned}
\] & 0.99 & 2.05 \\
\hline 9 & \[
\begin{gathered}
1.244 \\
(106.4)
\end{gathered}
\] & \[
\begin{aligned}
& -0.008 \\
& (-5.9)
\end{aligned}
\] & 0.99 & 1.82 \\
\hline 10 & \[
\begin{gathered}
1.229 \\
(57.9)
\end{gathered}
\] & \[
\begin{aligned}
& -0.006 \\
& (-2.5)
\end{aligned}
\] & 0.98 & 1.38 \\
\hline 11 & \[
\begin{gathered}
1.401 \\
(53.3)
\end{gathered}
\] & \[
\begin{aligned}
& -0.013 \\
& (-4.5)^{2}
\end{aligned}
\] & 0.96 & 0.87 \\
\hline 12 & \[
\begin{aligned}
& 1.270 \\
& (30.2)
\end{aligned}
\] & \[
\begin{aligned}
& 0.002 \\
& (0.4)
\end{aligned}
\] & 0.95 & 0.71 \\
\hline 13 & \[
\begin{aligned}
& 1.570 \\
& (79.8)
\end{aligned}
\] & \[
\begin{aligned}
& -0.018 \\
& (-8.3)
\end{aligned}
\] & 0.99 & 0.72 \\
\hline 14 & \[
\begin{gathered}
1.757 \\
179 . ?!
\end{gathered}
\] & \[
\begin{aligned}
& 0.000 \\
& (0.1)
\end{aligned}
\] & 0.99 & 0.85 \\
\hline 15 & \[
\begin{aligned}
& 1 . j 35 \\
& \text { (83.0: }
\end{aligned}
\] & \[
\begin{aligned}
& -0.002 \\
& (-1.6)
\end{aligned}
\] & 0.99 & 1.43 \\
\hline
\end{tabular}

Table 4.1: Estimation of the mark-up-equations





So far it was assumed that environmental expenditures will be included in the observable output-price to \(100 \%\) of course, alternative situations can be taken into account in which only parts of the environmental expenditures are included in the output-price.

As the supply of goods and services of one sector according to the input-output-table consists of home production and of imported goods of the same kind, the output-price of the total product of the sector has to be calculated as a mixture of the input-price \(p_{i t}^{I M P}\) and the home price \(p_{i t}^{I N L}\). In the simulations with the model the sectoral output-price is calculated according to:
(5.6) \(\quad p_{i t}=i m p_{i t} p_{i t}^{I M P}+\left(1-i m p_{i t}\right) p_{i t}^{I N L}\).

In this equation the input-prices are exogenous, the internal prices are endogenous according to the above mentioned concept, and the import relation is also endogenous.
6. Levels of employment and disposable income

The development of disposable income is determined by an approximation on the basis of the development of the two most important components: non-profit and profit income. As a main purpose of the analysis is to find out about the effects of environmental measures on employment, instead of a direct estimation of sectoral non-profit income the level of sectoral employment (i.e. non-profit income divided by the respective wage) is explained.

\subsection*{6.1. The sectoral levels of employment}

For each of the 15 sectors specific levels of employment \(b_{j t}\) are calculated as explained above. The wages as denominators are considered as exogenous variables; as there are no wages for the 15 sectors available, very similar wages referring to a very similar set of branches are used.

The specification of the equations for the sectoral levels of employment are based on the idea that employment is mainly determined by real production of the respective sector, the wage and an interest rate, and the price of the intermediate inputs. In some euquations also a time trend and the lagged level of employment was used. In sector 5 (mineral oil), an additional dummy variable was used. The sectoral prices for intermediate inputs are calculated according to
(6.1) \(p_{j t}^{V O R}=\sum_{i=1}^{15} a_{i j t}^{V O R} \cdot p_{i t}\).

In table 5.1 the results of the estimation are documented. The figures give the approximation and the prediction for 1971 up to 1983.
\begin{tabular}{|c|c|c|c|c|c|c|c|c|c|}
\hline Sektor & Konst. & \(p_{\text {jt }}^{\text {vor }}\) & \({ }^{1} \mathrm{jt}\) & \(r_{t}\) & \(\mathrm{x}_{\mathrm{jt}}\) & \(\mathrm{B}_{\mathrm{jt}-1}\) & t & \(\mathrm{R}^{2}\) & DW \\
\hline 1 & \[
\begin{aligned}
& 18.039 \\
& (3.31)
\end{aligned}
\] & \[
\begin{aligned}
& -18.888 \\
& (-2.85)
\end{aligned}
\] & \[
\begin{gathered}
0.1342 \\
(3.49)
\end{gathered}
\] & & & \[
\begin{gathered}
0.7166 \\
(10.95)
\end{gathered}
\] & & 0.97 & 2.38
3.25 \\
\hline 2 & \[
\begin{aligned}
& 375.112 \\
& (10.51)
\end{aligned}
\] & & \[
\begin{aligned}
& 9.2101 \\
& (3.27)
\end{aligned}
\] & \[
\begin{array}{r}
282.092 \\
(1.61)
\end{array}
\] & \[
\begin{aligned}
& 0.0049 \\
& (4.09)
\end{aligned}
\] & & & 0.99 & 3.25 \\
\hline 3 & \[
\begin{array}{r}
618.717 \\
(4.25)
\end{array}
\] & \[
\begin{array}{r}
402.921 \\
(3.17)
\end{array}
\] & \[
\begin{aligned}
& -39.947 \\
& 1-3.051
\end{aligned}
\] & \[
\begin{gathered}
-1881.32 \\
(-3.02)
\end{gathered}
\] & \[
\begin{gathered}
0.0131 \\
(3.57)
\end{gathered}
\] & & & 0.94 & 1.86 \\
\hline 4 & \[
\begin{gathered}
1094.51 \\
(6.34)
\end{gathered}
\] & \[
\begin{array}{r}
1492.06 \\
(3.32)
\end{array}
\] & \[
\begin{gathered}
-127.67 \\
(-3.26)
\end{gathered}
\] & \[
\begin{gathered}
-2556.99 \\
(-2.20)
\end{gathered}
\] & \[
\begin{gathered}
0.0099 \\
(4.025)
\end{gathered}
\] & & & 0.85 & 2.24 \\
\hline 5 & \[
\begin{aligned}
& 38.676 \\
& (1.61)
\end{aligned}
\] & & \[
\begin{array}{r}
-1.498 \\
(-1.58)
\end{array}
\] & & & \[
\begin{array}{r}
0.736 \\
(4.98)
\end{array}
\] & & 0.89 & 2.42 \\
\hline 6 & \[
\begin{gathered}
178.99 \\
(0.57)
\end{gathered}
\] & & \[
\begin{aligned}
& -30.90 \\
& (-4.38)
\end{aligned}
\] & & \[
\begin{aligned}
& 0.0158 \\
& (5.05)
\end{aligned}
\] & \[
\begin{aligned}
& 0.5044 \\
& (3.69)
\end{aligned}
\] & & 0.85 & 1.24 \\
\hline 7 & \[
\begin{gathered}
1479.82 \\
(1.69)
\end{gathered}
\] & & \[
\begin{aligned}
& -65.81 \\
& (-3.10)
\end{aligned}
\] & & \[
\begin{aligned}
& 0.0066 \\
& (3.95)
\end{aligned}
\] & \[
\begin{aligned}
& 0.3243 \\
& (1.44)
\end{aligned}
\] & & 0.94 & 2.26 \\
\hline 8 & \[
\begin{gathered}
1555.57 \\
(1.32)
\end{gathered}
\] & & \[
\begin{aligned}
& -90.87 \\
& (-2.85)
\end{aligned}
\] & & \[
\begin{aligned}
& 0.0156 \\
& (4.05)
\end{aligned}
\] & \[
\begin{aligned}
& 0.3629 \\
& (1.97)
\end{aligned}
\] & & 0.82 & 1.99 \\
\hline 9 & \[
\begin{gathered}
1582.58 \\
(2.22)
\end{gathered}
\] & & \[
\begin{gathered}
-105.21 \\
(-7.35)
\end{gathered}
\] & & \[
\begin{gathered}
0.0278 \\
(7.63)
\end{gathered}
\] & \[
\begin{aligned}
& 0.1812 \\
& (1.41)
\end{aligned}
\] & & 0.88 & 2.95 \\
\hline 10 & \[
\begin{array}{r}
2133.26 \\
(2.44)
\end{array}
\] & & \[
\begin{gathered}
-495.99 \\
(-4.11)
\end{gathered}
\] & & \[
\begin{aligned}
& 0.0179 \\
& (7.26)
\end{aligned}
\] & \[
\begin{aligned}
& 0.5342 \\
& (6.80)
\end{aligned}
\] & \[
\begin{gathered}
280.62 \\
(3.71)
\end{gathered}
\] & 0.99 & 2.25 \\
\hline 11 & \[
\begin{gathered}
373.74 \\
(0.76)
\end{gathered}
\] & & \[
\begin{aligned}
& -34.68 \\
& (-3.10)
\end{aligned}
\] & & \[
\begin{aligned}
& 0.0064 \\
& (2.85)
\end{aligned}
\] & \[
\begin{aligned}
& 0.4925 \\
& (2.62)
\end{aligned}
\] & & 0.94 & 1.92 \\
\hline 12 & \[
\begin{aligned}
& -54.48 \\
& 1-0.071
\end{aligned}
\] & & \[
\begin{aligned}
& -72.04 \\
& (-4.6)
\end{aligned}
\] & & \[
\begin{aligned}
& 0.0267 \\
& (5.85)
\end{aligned}
\] & \[
\begin{aligned}
& 0.3873 \\
& (3.32)
\end{aligned}
\] & & 0.96 & 1.60 \\
\hline 13 & \[
\begin{gathered}
726.79 \\
(9.73)
\end{gathered}
\] & & \[
\begin{gathered}
-2.88 \\
(-5.58)
\end{gathered}
\] & \[
\begin{gathered}
1356.87 \\
\quad(4.85)
\end{gathered}
\] & \[
\begin{aligned}
& 0.0021 \\
& (4.82)
\end{aligned}
\] & & & 0.84 & 2.52 \\
\hline 14 & \[
\begin{aligned}
& 14.31 \\
& (0.65)
\end{aligned}
\] & & & & \[
\begin{aligned}
& 0.0008 \\
& (8.13)
\end{aligned}
\] & \[
\begin{aligned}
& 0.5792 \\
& (8.12)
\end{aligned}
\] & & 0.99 & 2.91 \\
\hline 15 & \[
\begin{array}{r}
-149.19 \\
(-0.73) \\
\hline
\end{array}
\] & & \[
\begin{aligned}
& -3.042 \\
& (-2.12)
\end{aligned}
\] & & \[
\begin{aligned}
& 0.0039 \\
& (3.46)
\end{aligned}
\] & \[
\begin{aligned}
& 0.5605 \\
& (5.45)
\end{aligned}
\] & & 0.98 & 2.19 \\
\hline
\end{tabular}

Table 5.1: Estimation of the equation for the levels of employment





\subsection*{6.2. Profit income}

The nominal profit income is explained only as an aggregate and not on a sectoral basis. It is approximated along the lines of the nominal value of internal production \(\mathrm{PW}_{\mathrm{it}}^{\mathrm{NOM}}\). The following equation was used:
(6.2) \(E U_{t}^{N O M}=\alpha+\beta_{t} \cdot P W_{t}^{N O M}\).

The time-depending coefficient \(\beta_{t}\) is considered to be dependent on the wage:
(6.3) \(\beta_{t}=\alpha_{0}+\alpha_{1} \cdot l_{t}+\alpha_{2} t\).

So we get the following equation:
(6.4) \(E U_{t}^{N O M}=\alpha+\alpha_{o} \cdot P W_{t}^{N O M}\)
\[
\begin{aligned}
& +\alpha_{1}\left(I_{t} \cdot P W_{t}^{N O M}\right) \\
& +\alpha_{2}\left(t \cdot P W_{t}^{N O M}\right)
\end{aligned}
\]

The result of the estimation of this equation leads to:
\[
\begin{aligned}
& E U_{t}^{N O M}=-29894.5+0.4228 P W_{t}^{N O M}-0.0053\left(1_{t} \cdot \mathrm{PW}_{t}^{N O M}\right) \\
& \text { (-0.83) (6.26) (-5.57) } \\
& +0.0331\left(t \cdot \mathrm{PW}_{t}^{\mathrm{NOM}}\right) \\
& \text { (5.72) } \\
& R^{2}=0.99 ; D W=1.74
\end{aligned}
\]

The approximation and prediction for 1971 to 1983 is shown in the following figure.


\subsection*{6.3. Disposable income}

With the aggregate profit income and the sectoral levels of employment the two most important components of disposable income are known (the sectoral non-profit income can easily be calculated by mutliplying the level of employment of the sectors with the respective wages).

Contrary to the normal calculation of disposable income according to the national accounts (where disposable income is determined via the income identity) in this study a different procedure was used. The main reason for this is that with the normal approach one needs a very reliable approximation of all income components (for instance of transfer income).

A two-step-procedure was used: In the first step an "income-taxrate" and a "wage-tax-rate" \(s_{t}^{e}\) and \(s_{t}^{L}\) are defined:
\[
\begin{equation*}
s_{t}^{E}=\frac{E U_{t}^{N O M}-G_{t}}{E U_{t}^{N O M}} \tag{6.5}
\end{equation*}
\]
\[
\begin{equation*}
s_{t}^{L}=\frac{E A_{t}^{N O M}-\left(Y_{t}^{D}-G_{t}\right)}{E A_{t}^{N O M}} \tag{6.6}
\end{equation*}
\]
with \(G_{t}\) : distributed profits and income from property after taxes

Besides the development of the pure income tax rate, \(s_{t}^{E}\) also describes the changes of non-distributed profits and transfers as these components are included in ( \(E U_{t}^{N O M}-G_{t}\) ). Similarly \(s_{t}^{L}\) not only includes the pure wage-tax-rate but also transfers.

With these two "tax rates" together with the two income components, disposable income can be approximated in the following way:
(6.7) \(\varphi_{t}^{D}=\left(1-s_{t}^{E}\right) \cdot E U_{t}^{N O M}+\left(1-s_{t}^{L}\right) \cdot E \tilde{A}_{t}^{N O M}\)

\section*{7. Simulation experiments}

As was already mentioned the model can be characterized as a recursive model with the main parts:
1. endogenous final demand,
2. the production model with variable input-coefficients,
3. the price model,
4. endogenous income variables.

The "time-structure" of such an experiment is as follows: As the equations for prices and investment are determined by exogenous and/or lagged endogenous variables, these variables are determined in the beginning of the simulation. With calculated prices the input-coefficients can be determined; furthermore total consumption, being dependent only on prices and lagged disposable income, can also be calculated. Total consumption can then be split up into the consumption categories and - via the bridge-matrix - the sectoral supply of the fifteen sectors for consumption can be determined. With investment (also transferred into supplied goods and services by the sectors according to the bridge-matrix), consumption and the exogenous components of final demand (with investment for environmental purposes!), total final demand is known. According to the Leontief-inverse, with final demand and the matrix of the input-coefficients the sectoral production can be determined according to the following formula:
(7.1) \(\quad x_{t}=\left(I-A_{t}\right)^{-1} f_{t}\).

With sectoral production the levels of employment in the respective sectors and in consequence disposable income can be determined.

With all these informations the second round can be started.

Obviously, the simulation of endogenous variables has to be based on known values of the exogenous variables and especially the bridge-matrices. In order to make sure that the errors of simulation for the endogenous variables are not enlarged by errors because of erroneous prediction of the exogenous variables the model has been simulated only within the estimation period.

\subsection*{7.1. The results of some first simulation experiments}

In the first simulation experiments private and governmental investment for environmental purposes and current payments for environmental purposes were used. In order to come to comparable results all experiments started with an increase of the payments for environmental purposes of 2.8 bill. DM per year (this is on the average that amount of money that has been spent by private enterprises during the years of 1970 to 1983 for environmental investment; it stands for about 15 \% of the payments which the government and private enterprises altogether paid for the protection of the environment).

In table 7.1 the results of the following simulations are reported:
(a) Increase of private investment for environmental purposes by 2.8 bill. DM per year, financed by linear depreciation for ten years; price calculation with taking these costs into account to 100 \%
(b) like (a), but with the assumption, that the.private enterprises will have to spend an additional 840 mill . DM per year for running the new capital costs for environmental purposes;
(c) increase of the intermediate supply by the government by 2.8 bill. DM per year, financed by an increase of the prices;
(d) increase of governmental consumption by 2.8 bill. DM per Year (especially for hiring personel for environmental purposes), financed by direct taxes.
\begin{tabular}{|c|c|c|c|c|}
\hline & \multicolumn{2}{|l|}{additional measures for environmental purposes ( 2.8 bill. DM per year)} & \multicolumn{2}{|l|}{resulting changes (in \% per year)} \\
\hline Simulation experiment & private enterprises & government & total employment & total production \\
\hline (a)
(b) & \begin{tabular}{l}
expenses financed by depreciation, outputprices increased by these costs \\
investment only \\
like (a) + additional \\
expenses ( 840 mill . DM) \\
for running the new
\end{tabular} & & minimum...maximum
\[
\begin{array}{lll}
+0.11 \% & \ldots & +0.22 \% \\
+0.18 \% & \ldots & +0.33 \%
\end{array}
\] & \[
\begin{aligned}
& \text { minimum } \ldots \text { maximum } \\
& +0.14 \% \ldots+0.26 \% \\
& +0.25 \% \ldots+0.35 \%
\end{aligned}
\] \\
\hline (c)
(d) & & \begin{tabular}{l}
intermediate supply \\
financed by an increase of the respective prices \\
"consumption" \\
(hiring new personel), \\
financed by direct \\
taxes
\end{tabular} & \[
\left[\begin{array}{l}
+0.04 \% \\
+0.23 \%
\end{array} \ldots+0.35 \%\right.
\] & \[
-0.03 \% \ldots+0.35 \%
\]
\[
+0.078 \ldots+0.27 \%
\] \\
\hline
\end{tabular}

Table 7.1: Results of four simulation experiments

The results of the simulation experiments are different according to the different scenarios. This is especially true if one looks at the sectoral development. As far as the development of the total economy is concerned, in all experiments there is a slight increase of total employment, which almost always is accompanied by an increase of production.

The table shows that comparable measures undertaken by private enterprises will normally lead to a stronger increase in employment than if initiated by the government.

\section*{8. Conclusion}

After the specification of the model and its successfull application in some basic simulation experiments, the system will be used for more simulation experiments. It is the intention to formulate not only rather "theoretical" scenarios but also some more realistic ones. One first experiment in this direction is a simulation assuming that according to a certain regulation in the Federal Republic of Germany all one-way-bottles have to be replaced by several-waybottles (see J. Frohn, A. Bockermann, A. Faust (1990)).

As there are now new data available the model will be actualized in order to be able to come closer to the present economic reality.

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& \text { Sebastian }
\end{aligned}
\] & \begin{tabular}{l}
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\end{tabular} \\
\hline
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\title{
DOMESTIC EFFICIENCY AND BILATERAL TRADE GAINS, WITH AN APPLICATION TO CANADA AND EUROPE
}

\author{
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July 1991

By maximizing foreign earnings subject to material balance and factor endowment constraints, the most efficient reallocation of factor inputs in a bilateral, multi-sector model is determined. The Lagrange multipliers to the constraints are competitive prices. The consequent income increments are decomposed into X-efficiency, allocative efficiency and bilateral trade gains. An application of the model shows that, relative to observed bilateral trade, the Canadian comparative advantage vis-a-vis Europe is in mining, machines, food and leather \& footwear. In Europe, the other sectors (primarily manufacturing) would benefit from free bilateral trade.

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\section*{1. Introduction}

The creation of a common European market, to be completed, more or less symbolically, in 1992, is surrounded by suspicion. The promotion of internal free trade policies is accompanied by a deterioration of external trade relations. The Commission of the European Community frustrates North-American and Cairns group proposals to open markets to international competition. In fact, European policies in the Uruguay negotations of GATT are so detrimental, particularly to the Third World, that they more than offset the effects of development aid provided by the member countries. If protectionism was in the interest of the European Community, then the policy, however pitiful to others, would be rational, but not even this is the case. Economists offer two lines of analysis to support this point of view, the free trade argument and the study of tariffs and other impediments. The free trade argument is essentially a demonstration of the welfare superiority of unlimited exchange arrangements. Besides, applied studies attempt to identify the tariffs and other distortionary components of observed prices. By subtraction, the so called direct resource costs are isolated, signaling the comparative advantages of an economy.

In this paper, we attempt to consolidate the theoretical and applied lines of analysis in the field of international trade. We make a tour de force by determining what the free trade pattern between Europe and a close partner economy, Canada, would be, given only respective technologies, endowments and final demand necessities. The consequent free trade pattern is then compared to the actual one. The pattern of specialization that would emerge under free trade is indicated and the welfare gains are estimated. From the view point of operations research, the problem is to maximize surplus (commodity output in excess of observed final demand), valued at world prices, subject to two sets of constraints for each country. The first set of constraints consits of the material balances: gross output must be at least equal to intermediate demand plus final demand plus surplus. The second set of constraints, comprises labor and capital endowments \({ }^{1)}\).

Part of the surplus will result from the elimination of capacity underutilization, rather than to the reallocation of activities between Europe and Canada. Furthermore, the efficiency gain involved in full re-
source utilization will be decomposed into an X-efficiency and an allocative efficiency component, reflecting excess capacities and misallocations of labor or capital. Gains to international specialization are estimated residually. By fixing technical coefficients, we eliminate one source of efficiency, namely intrasectoral substitutions. In this regard, we provide conservative estimates of the gains to free trade.

The very concepts of specialization and allocative efficiency require some intersectoral substitutability, however. We instill this ingredient by the assumption that capital and labor are malleable across sectors. This assumption yields an overstatement of the allocative efficiency and gains to free trade estimates. If capital and labor are, to some extent, sector specific, then the magnitudes of our results will be lower. The issue is a matter of data availability, since it would merely involve a disaggregation of the factor constraints, but bears little on the analytical structure of our model, detailed in the next section. An analysis of prices follows in section 3. Section 4 introduces the data. Free trade results are presented in section 5 and discussed in the conclusion.

\section*{2. The model}

Woodland (1982) develops a neoclassical model of international trade with fixed domestic endowments, and commodities which are tradable or nontradable, and intermediate or final. We make it operational by substituting Leontief production functions for technologies and foreign earnings for social welfare. Consider one of the constituent economies, say Europe. \(x\) is a gross output vector, with 26 components for various commodities. Intermediate demand is \(A x\), where \(A\) is the square matrix of technical coefficients. The production of each unit of output \(x_{j}\) requires \(a_{i j}\) units of output i. Observed final demand, that is household and government consumption, investment and net exports, is denoted by f. It includes observed net exports to Canada, say \(h\). In other words, \(f=g+h\), where \(g\) is final demand excluding net exports to Canada. The surplus generated in the course of our efficiency analysis will be denoted by \(y\). In the sequel, italic symbols represent Canadian items. For example \(y\) will denote Canadian surplus.

Imagine our two countries (Europe and Canada) form a customs union. Commodities can be freely exchanged between the two countries. Each country has its own technology, but can benefit from the superior technology of its partner by importing its production. Labor and capital are perfectly malleable and can freely move within each country, but cannot cross borders. We wish to allocate output across the two countries and the 26 sectors in each of them so as to maximize joint surplus, without depleting observed final demand, including net trade with the rest of the world. In other words, both countries have to be jointly self-sufficient in satisfying existing final demand. Formally, the objective function to be maximized is \(\pi(y+y)_{T}\), where \(\pi\) is a row vector of world prices and subscript \(T\) selects the tradable commodities, \(1, \ldots, 18 .{ }^{21}\) The motivation of this objective function can be given for small, open economies. The smallness means that world prices can be considered as given: world demand for all commodities is perfectly elastic. The openness means that maximization of foreign earnings is an objective consistent with any bilateral welfare function. This can be proved just like the first welfare theorem, by which an equilibrium is Pareto efficient with respect to individual utility functions.

The maximization of foreign earnings has to be performed under a certain set of inequality constraints. The production of each commodity has to be sufficient to meet the intermediate input requirements in the production of the other commodities, plus the exogenous final demand and the endogenous surplus. For Europe, the so called material balance reads
\[
\begin{equation*}
x \geq A x+f+y \tag{1}
\end{equation*}
\]

Similarly, for the other economy (Canada), we have \({ }^{3)}\)
\[
\begin{equation*}
x \geq A x+f+y \tag{2}
\end{equation*}
\]

Output will be constrained by factor endowments,
\[
\begin{equation*}
1 x \leq L \tag{3}
\end{equation*}
\]
\[
\begin{equation*}
k x \leq k \tag{4}
\end{equation*}
\]
where 1 is a row vector of labor coefficients and \(L\) is the labor force. The capital constraint items are analogous. Similarly, for Canada we have
\[
\begin{align*}
& l x \leq L  \tag{5}\\
& k x \leq K . \tag{6}
\end{align*}
\]

For the tradable commodities, the self-sufficiency constraint is obtained by requiring
\[
\begin{equation*}
\mathrm{y}_{\mathrm{T}}+y_{\mathrm{T}} \geq 0 \tag{7}
\end{equation*}
\]

Both countries must jointly meet their observed final demands. For the nontradable commodities, by definition, the inequality has to be strengthened to
\[
\begin{align*}
& \mathrm{y}_{\mathrm{N}} \geq 0,  \tag{8}\\
& y_{\mathrm{N}} \geq 0 . \tag{9}
\end{align*}
\]

In the absence of inventories, the model is completed by the nonnegativity constraints on production
\[
\begin{align*}
& x \geq 0,  \tag{10}\\
& x \geq 0 \tag{11}
\end{align*}
\]

The customs union problem is therefore to maximize \(\pi(y+y)_{T}\) subject to (1) to (11). The solution value, the optimal surplus, cannot be ascribed totally to the gains from free trade. To identify efficiency components of the solution, we shall solve two additional optimization problems, the autarky models with and without sectoral reallocations, yielding respectively the gains attributable to X-efficiency only, and those attributable to both X-efficiency and domestic allocative efficiency. The pure gains from free trade are obtained by substracting from the solution of the
customs union problem the solution of the autarky problem with domestic allocative efficiency.

Under autarky, the surplus values are restricted to domestic increases, i.e. the joint self-sufficiency constraint (7) is replaced by
\[
\begin{align*}
& y_{\mathrm{T}} \geq 0,  \tag{12}\\
& y_{\mathrm{T}} \geq 0 . \tag{13}
\end{align*}
\]

The European domestic allocative efficiency is obtained by maximizing \(\pi y_{T}\) subject to (1), (3), (4), (8), (10) and (12), and likewise for Canada \({ }^{4}\).

To restrict the surplus to the extraction of X-efficiency, additional constraints must be imposed to prevent the sectoral reallocation of resources. In the case of Europe, these constraints are that outputs may not exceed full capacity levels of the sectoral capital stocks. Also, labor may be recruited from the pool of the unemployed, but not from other sectors. In short,
\[
\begin{equation*}
k_{i} x_{i} \leq K_{i}\left(\text { all i) }, \operatorname{lmax}\left\{x, x^{0}\right\} \leq L\right. \tag{14}
\end{equation*}
\]
where max operates on each element of the vector, \(x^{0}\) is the observed output vector, and \(K_{i}\) is the capital stock in sector i. Note that (14) insures (4).

In the case of Canada, the reallocation preventing constraints must be related to the output matrix, i.e. the presence of secondary outputs. We therefore proceed to a change of variables \(x=V^{T} \xi\), where \(V\) is the sector by commodity output matrix (the so called make table), and 5 is the vector of constants such that \(\xi=i\) corresponds to observed outputs (i being a vector with all entries equal to 1 ). Given that \(A=U V^{-T}\) (see Kop Jansen and ten Raa, 1990; the superscript -T denoting the composition of transposition and inversion, two commuting operations), and \(\tau=\underline{L} V^{-T}\) where \(U\) is the commodity by sector input matrix (the so called use table) and \(\underline{L}\) the row vector of sectoral labor employments, we can reformulate the Canadian \(X\)-efficiency problem as \(\max \pi y_{\mathrm{T}}\) subject to
\[
\begin{equation*}
\left(V^{T}-U\right)_{5} \geq f+y \tag{15}
\end{equation*}
\]
and
\[
\begin{equation*}
\underline{L} \xi \leq L \tag{16}
\end{equation*}
\]
as well as (9), (13) and
\[
\begin{equation*}
\xi \leq c^{-1}, L \max \{\xi, i\} \leq L \tag{17}
\end{equation*}
\]
where \(c^{-1}\) is a column vector of inverse sectoral capital utilization rates. Notice that \(\xi\) replaces \(x\), (15) replaces (2), (16) replaces (5). and (17) insures the capital constraint (6) sector by sector and prevents reallocations of labor across sectors.

\section*{3. Prices}

The Lagrange multipliers associated with the material balance, (1) and (2), are the shadow prices of the commodities in either economy and will be denoted by row vectors \(p\) and \(p\), respectively. The Lagrange multipliers associated with the factor endowments, (3-6), are the shadow prices of labor and capital in either economy and will be denoted \(w, r\), and \(w, r\), respectively. The Lagrange multipliers associated with the pooled nonnegativity constraints on \(y_{T}\) are tariffs of the tradables which a customs union would require to protect internal production, since a relaxation of such a constraint can be visualized as domestic production substitution by imports from the rest of the world. Per unit, the net gain involved would be the internal production price minus the world price. These tariffs are denoted by row vector \(\tau\). In the same vein, the Lagrange multipliers associated with the separate nonnegativity constraints on \(y_{N}\) are domestic production prices of the nontradables, denoted by row vectors \(t\) and \(t^{5)}\). The Lagrange multipliers associated with the nonnegativity constraints on output levels, \(x\) and \(x\), are slack variables, denoted \(s\) and \(s\), respectively. Price relationships are established by setting up the dual program (Schrijver, 1986, p. 90),
\[
\begin{aligned}
& \text { minimize } w L+r K-p f+w L+r K-p f \\
& w, r, w, r, p, p
\end{aligned}
\]
subject to \(p \leq p A+w l+r k, p \leq p A+\omega l+r k, p_{T}=p_{T} \geq \pi, p_{N}, p_{N} \geq 0\).

If the price of a tradable commodity exceeds world price, then its total surplus is zero. \({ }^{6)}\) Consequently, any positive total surplus is signaled by the condition that price is at minimum, world levels. These commodities constitute the joint Canadian-European comparative advantage vis-a-vis the rest of the world. This comparative advantage can also be located by checking the country terms of total surplus. For all other commodities, the surplus terms cancel and, therefore, constitute bilateral trades. The origins of these trades locate the bilateral comparative advantages. \({ }^{7}\) )

The gain to efficient allocation of resources within Europe and Canada jointly is given by the value of the primal program, \(\pi y_{T}+\pi y_{T}\). The terms show the location of the surplus production. The induced income need not be distributed in proportion to the efficiency gains, even though the latter are given in terms of real income improvements. More precisely, by the main theorem of linear programming (Schrijver, 1986, p. 90), the values of the primal and dual programs are equal:
\[
\pi y_{T}+\pi y_{T}=w L+r K-p f+w L+r K-p f .
\]

Here \(w L+r K-p f\) is European factor income net of base purchases and similarly for Canada. We have distributed the surplus according to these net income terms. In principle, at least when the model is appropriately respecified, one term may be negative, in which case we have the problem of disadvantageous trade. In general, net income shares will be positive, but not proportional to surplus shares, yielding the problem of unequal trade.

Recall that the gain to bilateral trade is separated out by replacing the pooled nonnegativity constraint of tradables by domestic constraints. The tightening of constraints yields a reduction of the value of the objective function which is precisely the gain to trade. The separate nonnegativity constraints yield that all commodities must now be produced in each country. Consequently, there is no slack in the price relationships: domestic prices match production costs. The traditional Leontief value equations apply, without the substitution of coefficients by superior foreign ones, and allow prices to be decomposed into labor and capital values. Typically, prices will be higher. We thus have a framework to
compare prices with or without bilateral trade and to check the Ricardian theory of comparative advantage by which autarky prices in the two countries predict the pattern of bilateral trade. Also, the framework can be used to check the Heckscher-Ohlin theory of comparative advantage by which the factor contents determine the pattern of trade. Finally, the imposition of sectoral constraints, that rule out reallocations, will reduce the values of the objective function by amounts which can be ascribed to domestic allocative efficiencies, reducing the values to X-efficiencies which can be captured by increasing observed cutputs to full capacity levels. A degree of freedom needed for full employment of both factor inputs is no longer available, and the phenomenon of complementary slackness suppresses either the shadow wage rate or the shadow rental rate of capital, yielding a traditional input-output pattern \({ }^{8}\) ).

\section*{4. Data}

The European data base will be presented now. \({ }^{\text {9) }}\) The transactions matrix and the final demand vector were kindly supplied to us by Eurostat (1989). The data are published in ten Raa and Chakraborty (1991). All output flows to the non-market services sectors ( \(\mathrm{R}-44\) sectors 810,850 , 890, 930) are relegated to final demand. Sectoral labor employment figures are published by Eurostat (1986), at national levels \({ }^{10 \text { ). The employment }}\) data are aggregated into the \(\mathrm{R}-44\) classification by replacing the last digit of a branch code by zero. A few transfers, 11) which seem reasonable to us, and aggregation according to table 1 , yield the sectoral employment data listed in table 2. The labor force figure, included in table 2, is the total labor force from Eurostat (1985) minus the employment in the non-market services. Capital stocks data were kindly released by Eurostat (1990). They are easily expressed in millions ECU, using the exchange rates given in Eurostat (1986), and reproduced in table 2. The E.C. capital accounts classification is the so-called R-25 system (see table 1). Some data are missing altogether. For others, only subtotals are available. Since the purpose is to construct sectoral capital/output coefficients, we fill data gaps by assuming that capital/output ratios in the other countries extend to where they are missing or partially known. \({ }^{12 \text { ) }}\) The capital stock transformation from R-25 to our classification involves a few aggregations and a few disaggregations. The aggregations are trivial
summations. The disaggregations concern the split of the \(\mathrm{R}-25\) sectors 13 , 14,17 and 20 into our \(10+11+12,13+14,16+18\) and \(20+26^{*}\), respectively, where \(26^{*}\) is part of 26 , namely \(R-44\) sector 55 . We disaggregate by capital costs, or, the closest available, net operating surplus. \({ }^{13)}\) The consequent estimates of total capital stock by our classification of sectors is given in table 2. Unfortunately, utilization rates are not available at sectoral levels. We have to use a macro figure and apply it to all sectors alike. The figure used in table 2 is the E.C. manufacturing capacity utilization rate from the Commission of the European Communities (1984, p. 17), \(81.2 \%\).

The Canadian data base, involving one country only, is straightforward. The use and make tables are directly available from Statistics Canada (1987). They relate to business activities only. Sectoral labor employment and capital stock data were kindly released by Statistics Canada (1990 and 1990a). \({ }^{14)}\) The latter table also contains the capital utilization rates, \(c\), from Government of Canada (1984) \({ }^{15)}\), and from Bank of Canada (1983) for the construction sector. Disaggregations by wage funds and capital funds respectively yield the labor and utilized capital employment reported in table 3. The disaggregations involve the following sectors of our classification: \(2+3+4^{16)}, 14+15(\text { capital only })^{17)}\). \(21^{18)}, 22+23\) (capital only) \({ }^{19)}\) and \(26^{20}\). We have included in table 3 the labor force figure, taken from Statistics Canada (1989) and the total capital stock figure computed from table 6. We have also added the exchange rate to table 3 , to express the capital stocks in millions ECU. The source is IMF (1985).

\section*{5. Results}

The combined results of domestic efficiency and free bilateral trade are given in table 4. The gross output column shows that Canada specializes in four tradables: mining (2), machines (7), food (10) and leather \& footwear (14). The surplus column shows that Canada generates surpluses in each of those sectors and that they are wholly exported to Europe. In mining and in leather \& footwear, Canadian supplies fulfill all European demands, while in machines and in food, Canadian imports must be augmented by European production. Consequently, Canadian production costs of mining and leather \& footwear are less than in Europe, while those of
agricultural and machines are equal in the two economies. \({ }^{21)}\) Thus, Canada is even more a resource oriented economy (mining and the insignificant leather \& footwear sectors) than observed exports suggest, with, moreover, competitive food and machines sectors. The net exports (from Canada to Europe) are relative to observed levels of bilateral trade. For sectors 1 , 3-6, 8-9, 11-13 and 15-18, free trade would imply scope for European exports. The manufacturing sectors are among them. Two sectors feature European surplus in excess of Canadian requirements: petroleum \& natural gas (3) and tobacco (12). They constitute the joint comparative advantage vis-a-vis the rest of the world. Domestic production of nontradables is just to fulfill intermediate demands and exogenous final demand. It may be of interest to note that this result persists even when nontradables are included in the objective function.

Total surplus is 479,003 millions ECU (29\%) in Europe and 54.944 (35\%) in Canada, where the percentages in parentheses are GDP shares, i.e. commodity quantities of final demand. The income distribution is determined by the terms of the dual objective function: 434,943 millions ECU (27\%) for Europe and 99,005 (63\%) for Canada. Surplus accrues disproportionally more to Canada, due to its slightly superior factor productivities.

Perhaps more interesting than a regional income distribution of total surplus is its decomposition in efficiency improvements due to full and optimal utilization of domestic resources and to bilateral trade gains a customs union may bring about. The domestic efficiency components are reported in table 5. Here the two economies are separated, apart from observed levels of bilateral trade. Positive surpluses or minimum prices indicate sectors with comparative advantages in the absence of a customs union (sectors 2 and 7 in Canada and 3 and 12 in Europe). Note that they persist as Canadian exports and European surplus generators in the presence of a customs union, as we have seen in table 4. For each tradable commodity, the two autarky prices (table 5) span the free trade price (table 4). However, autarky prices do not predict the pattern of bilateral trade (table 4), except for the minima, which signal exports indeed. European factor productivities are not affected by the separation of the economies. Compared to Europe, Canada seems to be relatively short on capital, as evidenced by a substantially higher rate of return. The shadow prices
of labor reveal a greater scarcity in Europe. The total value of Canadian surplus as a percentage of GDP goes from \(35 \%\) to \(20 \%\), a drop of \(75 \%\) which can be identified as the gains to free trade. For Europe, the drop is from \(29 \%\) to \(21 \%\), indicating that a great deal of surplus can be achieved just by eliminating domestic inefficiency. Income wise the pattern is accentuated. Almost the entire European income gains in table 4 (amounting to \(27 \%\) of GDP) can be ascribed to domestic inefficiency removal (namely \(21 \%\) of GDP), whereas in Canada, it plays only a minor role ( \(20 \%\) of GDP in table 5 compared to \(63 \%\) in table 4).

The inefficiencies in the Canadian and particularly European economies can be decomposed further into \(X\)-inefficiency and allocative inefficiency. The positive surplus entries in table 6 locate the slack in the economies. Europe has slack in all tradable sectors, except agriculture (1), food (10), textiles \& clothing (13), leather \& footwear (14), wood products (16) and other manufactures (18). The shadow wage rates confirm that workers are short in Europe and long in Canada. For capital, it is the other way round, but national rates of returns do not exist in the X-efficiency program because capital is modeled sector specifically. Comparison of tables 9 and 10 shows that European surplus drops further from \(21 \%\) to \(5 \%\), leaving three quarters to allocative inefficiencies. In Canada, the further drop is from \(20 \%\) to \(9 \%\), leaving half to allocative inefficiencies. To summarize, we have ascribed the European share of surplus mostly to the elimination of allocative inefficiencies and the Canadian share mostly to gains to trade. To some extent this finding reflects the sizes of the two economies. Comparison of the bottom entries of tables 8 and 9 yields that the absolute gains to free bilateral trade are 94,870 millions ECU for Europe and 67.648 millions ECU for Canada. One might say that our solution is a Walrasian equilibrium and that it resides on the Edgeworth contract curve of efficient bilateral allocations, where the joint benefits are distributed \(60 / 40\) to the advantage of Europe.

We have seen that Europe has abundant capital and Canada abundant labor, relatively speaking. Trade theories would predict that Canadian exports are labor intensive. We have computed the capital/labor intensities both direct and by total content, to be in the spirit of either Deardorff (1979) or Leontief (1953), respectively. The intensities are reported in table 7 . Now, table 4 identified the free Canadian exports as
commodities 2, 7. 10 and 14 . Their ranks in Canadian capital/labor intensities (counted from below among the tradables) are 17, 2, 9 and 6 (direct) and \(16,4,8\) and 3 (total), according to table 7. We find it impossible to claim that these are at the lower end of the 18 sectors of tradables. In Europe, these items are the imports and one might also expect a low factor intensity ratio. Here the ranks are \(13,16,6\) and 1 (direct) and \(17,6,11\) and 1 (total). These are not at the lower end either. Neither does comparison with the Canadian ranking suggest a pattern. While relative factor intensities tell no story, it is interesting to note that Europe has greater total capital/labor intensities for all tradables except metal products. In other words, European technology has adapted to the abundance of capital. This process, however, involves little substitution of labor relative to Canadian technology in view of their equal shadow wage rates (table 4). The abundance of European capital shows not only in low capacity utilization rates, but also in low capital productivity rates. In this regard, Canadian technology outperforms European technology through modest levels of capital inputs.

In the last table, we present the observed bilateral trades obtained by our aggregation of Statistics Canada (1983) data. By adding the improvements computed in this paper (table 4), we obtain the optimum bilateral net trades (table 8, last column). Two times out of three, the optimal direction of trade does not conform to the actual direction.

\section*{6. Conclusion}

If Canadian-European trade were free, income levels in both economies would increase as a result of specialization of economic activities. The Canadian comparative advantage vis-a-vis in Europe rests in the sectors mining (2), machines (7), food (10) and leather \& footwear (14). Europe has a comparative advantage in all other sectors, including manufacturing. In either economy, the increase of net exports in sectors having a comparative advantage outweighs the decrease of net exports in the other sectors under free bilateral trade.

The joint Canadian-European comparative advantage vis-a-vis the rest of the world rests in two sectors, petroleum \& natural gas (2) and tobacco products (12), both in Europe. It is interesting to note that these "sin" sectors are heavily taxed. Apparently, they have been able to
offset this pressure by input reductions. The consequent productivity performances cause the comparative advantages. These observations support the views of Schumpeter rather than Keynes.

In autarky, Europe is shorter in labor but more abundant in capital than Canada. Free markets, however, would not produce migratory pressure nor capital movements. Assuming a common depreciation rate and equal tax treatments, the rates of return on capital would be equalized. In other words, there would be no pressure to invest in Canada, while European capital requirements can be fulfilled by enhancing the utilization of existing capacities. Free European exports to Canada need not be more capital intensive, however. The Heckscher-Ohlin theorem is invalidated by the presence of tradable intermediate goods and a difference in technology (Canada has an edge in capital requirements), in agreement with Batra and Casas (1973) and Deardorff (1979). The Ricardian theorem--that domestic production prices in the absence of free bilateral trade predict the pattern trade-holds for extreme cases only, namely sectors mining (2), petroleum \& natural gas (3), machines (7) and tobacco (12) \({ }^{22}\) ), in agreement with the theoretical result that the Ricardian prediction breaks down when there are more than two traded commodities (Drabicki and Takayama, 1979, and Woodland, 1982).

The gains to free bilateral trade are in absolute terms greater for Europe, but in relative terms more important to Canada, where they dominate other potential efficiency gains. In Europe, however, there is more scope for efficiency, particularly allocative efficiency. Hopefully, this will be achieved upon completion of the European common market.

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\section*{Footnotes}
1) A rudimentary model was initially proposed by ten Raa and Chakraborty (1991)
2) Tradable commodities are those for which Statistics Canada (1983) reports data of foreign trade.
3) As a matter of fact, the surplus will always make the equality hold in (1) and (2). It is for numerical and interpretational ease that we keep the inequalities.
4) Numerically, it is advisable to first solve the autarky problem and then to solve the customs union problem, releasing (12) and (13) into (7), starting from the previously obtained outcome as initial value.
5) Since non-tradables have by definition no world price, we have not included any surplus derived from their production in the objective function.
6) A similar observation can be made on nontradables, and then even per country, but is trivial in view of the objective function of the primal program.
7) Strictly speaking, these bilateral comparative advantages are only relative to observed levels of bilateral trade and this qualification may be ignored only if the computed surplus trade ( \(y_{i}\) ) overwhelms the observed bilateral trade ( \(h_{i}\) ). This condition is fulfilled in the empirical part of this paper.
8) For completeness, we mention that in the autarky decomposition calculations, the two economies separate out and all surplus gains acrue to domestic factor inputs by the main theorem of linear programming.
9) Eurostat ( 1976 , p. 162-67) uses 44 sectors in the input-output classification and 25 sectors in the capital accounts. Statistics Canada (1987, 1990a) uses 50 industries and 92 commodities in the M-level input-output classification and 29 industries in the capital accounts. In either economy, the labor accounts follow basically the input-output classifications, slightly more aggregated. The so called R-44 and M-level classifications have been aggregated into a common base of 26 sectors. Non-market services in Europe, which correspond to non-business activities in Canada, are treated as exogenous in this study. The labor and capital requirements in these sectors are subtracted from the total labor and capital availabilities, whereas their intermediate input requirements are treated as exogenous production requirements in each of 26 remaining sectors by inclusion in the final demand vector. The sectors are listed 1 to 26 throughout this study. These codes and the names we have assigned to the sectors are listed in the first column of table 1. The second column shows how they can be obtained by aggregating the R-44 sectors. The third column relates them to the European capital sector classification. The fourth and fifth columns show how the sectors can be obtained by aggregating the \(M\)-level
industries and commodities, respectively. The sixth column relates them to the Canadian capital sector/classification.
10) Belgium data were provided to us by Eurostat (1990a).
11) Belgium shows a great reduction of market services n.e.c. in favor of classified services compared to previous data. We have done the same with sectors 79 (market services n.e.c.) of the first six countries. The recipient \(\mathrm{R}-44\) sectors are 57 (wholesale \& retail), 65 (auxiliary transport) and 69 (credit \& insurance). (Unlike Belgium, sectors 55, 71 and 77 are ignored, as Eurostat (1986) input-output table has blanks only in these rows and columns.) For classification consistency, the key for the redistribution must be taken from the input-output table to be used. The only possibilities are gross value added at market prices and actual output. We have chosen the former, which are for sectors \(57,65,69\) and 79: 238019, 24432, 116606 and 108921, using Eurostat (1989). These figures include Belgium. We do not correct for this, since the classification of data across the sectors under consideration seems to vary between national accounts and the consolidated European input-output table. The shares of the first three figures are 48.78\%, 5.01\% and 23.90\%. Applied to employment of market services n.e.c. of Denmark + FRG + France + Italy + Netherlands + U.K. (27851), this yields transfers of 13586, 1395 and 6656 (thousand of persons) to sectors 57,65 and 69, respectively. Employment in the non-market services has been netted out of employment in sector 26 on the basis of their value added share of \(71.16 \%\).
12) In R-25 sector 1 (agriculture), Belgium and Netherlands stock data are missing. The capital/output ratio in the remaining countries, using Eurostat (1990) ard Eurostat (1986) is 2.289. Multiplication with Belgium and Netherlands outputs yields stock estimates. Addition of the known stocks of the other countries yields an estimated agriculture stock of 314457 millions ECU, reported in table 5 . In R-25 sectors \(8,9,10,11\) and 12, Denmark is missing. The same procedure yields Danish stock estimates 1154.2 , 1922.8, \(294.0,760.6\) and 915.7 millions ECU, respectively. The total Danish stock in these sectors is known, however, 7182. We have inflated the Danish stock estimates by a common factor to meet the total. For \(R-25\) sectors 20 and 22 the problem is the same as for sector 1 (agriculture). For \(R-25\) sectors 23,28 and 29 stock data availability is as follows.


First, we disaggregate the French sectors \(28+29\), using the capital/output ratios of F.R.G. + Italy + U.K. and deflation to meet the known total. Next, we disaggregate the Danish sectors \(23+28+29\), using the capital/ output ratios of F.R.G. + France + Italy + U.K. and a tiny inflation to meet the known total. Finally we fill the Belgium and Netherlands gaps using the capital/output ratios of Denmark + F.R.G. + France + Italy + U.K. R-25 sectors \(24+25+26\) are treated as a conglomerate, since our own classification does not have this detail. Of the conglomerate, only
the Belgium and Netherlands data are missing and estimated using the capital/output ratio from the other countries. The same holds for R-25 sector 27.
13) This proxy is missing for France and Italy. We fill this gap by estimating net operating surplus using the net operating surplus/gross value added at market prices ratio of Denmark + F.R.G. + Belgium + Netherlands + U.K. and applying it to the gross value added at market prices figures of France and Italy.
14) The stock of sector 26 (in the Canadian capital classification) is confidential and has been suppressed by Statistics Canada (1990a).
15) For industries 1 and 2 at the \(M\)-level classification, we took the rate of industry 8 since the latter is its main user. For industry 3, we took the weighted average of industries 16 and 18 with weights from the \(U\)-matrix of 1980. For industries \(11+13\) and \(14+15\), a weighted average of sectoral rates was computed, with weights taken from the \(V\)-matrix (industry totals). For industry 12 it was assumed to be the same as for industries \(11+12\) (i.e. plastics \& rubber). For industries 30-33 and 35-50, since the use of their output is widespread, we took the industrial utilization rate of \(83.8 \%\).
16) The wage funds of \(M\)-sectors \(4+7,5\) and 6 are, respectively, 3081.4 , 1150.6 and 162.2. The consequent disaggregation of employment is \(300593=\) \(210789+78709+11096\) (thousand personhrs). Adding M-sector 26 employment to the middle term and M -sector 25 employment to the last term, yields 210789, 111257 and 114933. Since total employment is \(10,143,535\) persons, working 18090468 thousand personhours, multiplication with the ratio of the latter to the former, yields the reported labor figures. The capital funds of \(M\)-sectors \(4+7,5\) and 6 are, respectively, 5496.1, 8026.8 and 150.2. The consequent disaggregation of the utilized stock is \(48152.192=19355.468+28267.767+528.955\) (millions dollars). Adding M-sector 26 utilized stock to the middle term and M-sector 25 utilized stock to the last term, yields the reported figures.
17) The capital funds of M-sectors 13 and 11 are, respectively, 121.1 and 155.4. The consequent disaggregation of the utilized stock is \(1743.700=\) \(763.696+980.004\) (millions dollars). Adding M-sector 12 utilized stock to the last term, yields the reported figures.
18) These figures have been taken out of services by wage fund and capital fund shares.
19) These stock figures were obtained by disaggregation, using capital fund shares.
20) Lodging \& catering has been subtracted.
21) This is the phenomenon of complementary slackness between outputs and cost-price relations, noting the equality of prices whenever commodities are tradable.
22) These sectors show minimum prices in table 9.

Table 1. Classification of sectors and European and Canadian (dis)aggregations.
\begin{tabular}{|c|c|c|c|c|c|c|}
\hline & Present Study 26 sectors & \[
\begin{aligned}
& \text { R-44 } \\
& 44 \text { sectors }
\end{aligned}
\] & E.C. capital 25 sectors & \begin{tabular}{l}
M-level \\
50 industries
\end{tabular} & \begin{tabular}{l}
M-level \\
92 commodities
\end{tabular} & Canadian capital 29 industries \\
\hline 1 & Agriculture & 010 & 1 & 1,2,3 & 1,2,3,4,5,6 & 1,2,3 \\
\hline 2 & Mining & 030,050,110,130 & 2.5 & 4.7 & 7,8,9,13 & 4 \\
\hline 3 & Petroleum \& Natural Gas & 070 & 2 & 5,26 & 10,11,62,63 & 4,21 \\
\hline 4 & Non-metallic Minerals & 150 & 6 & 6,25 & 12,60,61 & 4,20 \\
\hline 5 & Chemical Products & 170 & 7 & 27 & 64,65,66,67 & 22 \\
\hline 6 & Metal Products & 190 & 8 & 20,21 & 45,46,47, 48, 49, 50,51,52 & 15,16 \\
\hline 7 & Machines & 210,230 & 9.10 & 22 & 53,54 & 17 \\
\hline 8 & Electrical Goods & 250 & 11 & 24 & 58,59 & 19 \\
\hline 9 & Transportation Equipment & 270,290 & 12 & 23 & 55,56,57 & 18 \\
\hline 10 & Food & 310,330.350 & 13 & 8 & \(14,15,16,17,18,19,20,21,22\) & 5 \\
\hline 11 & Beverages & 370 & 13 & 9 & 23,24 & 6 \\
\hline 12 & Tobacco Products & 390 & 13 & 10 & 25,26 & 7 \\
\hline 13 & Textiles \& Clothing & 410 & 14 & 14,15 & 31,32,33,34.35 & 10 \\
\hline 14 & Leather \& Footwear & 430 & 14 & 13 & 30 & 9 \\
\hline 15 & Rubber \& Plastic & 490 & 16 & 11,12 & 27,28,29 & 8.9 \\
\hline 16 & Wood Products & 450 & 17 & 16.17 & 36,37,38,39 & 11.12 \\
\hline 17 & Paper \& Printing & 470 & 15 & 18,19 & 40,41,42,43,44 & 13.14 \\
\hline 18 & Other Manufactures & 510 & 17 & 28 & 68,69 & 23 \\
\hline 19 & Construction & 530 & 19 & 29 & 70,71,72 & 24 \\
\hline 20 & Wholesale \& Retail & 570 & 20 & 35.36 & 80,81 & 28 \\
\hline 21 & Lodging \& Catering & 590 & 23 & 44 & 88 & 30 \\
\hline 2 & Transportation & 610,630,650 & 24,25,26 & 30,31,32,50 & 73,74.90 & 25 \\
\hline 23 & Communication & 670 & 27 & 33 & 75,76,77 & 25 \\
\hline 24 & Utilities & 090 & 2 & 34 & 78,79 & 27 \\
\hline 25 & Finance & 690,730 & 28 & 37,38,39,40 & 82,83 & 29 \\
\hline 26 & Services & 790 & 20,29 & 41,42,43 & 84,85,86,87,89 & 30 \\
\hline & & 550,710,750,770 & & 45,46,47,48,49 & 91,92 & \\
\hline
\end{tabular}

Note: R-44 sectors \(810,850,890\) and 930 and E.C. capital sector 22 pertain to non-market services, which are excluded from sector 26 and modeled as exogenous in the present study.

Table 2. Labor and capital in Europe, 1980. Table 3. Labor and capital in Canada, 1980.

Sector Employment Utilized gross stock
\begin{tabular}{rrr}
\hline & & \\
1 & 7278 & 255339 \\
2 & 2006 & 131252 \\
3 & 199 & 335647 \\
4 & 1539 & 70347 \\
5 & 1729 & 141435 \\
6 & 2806 & 65256 \\
7 & 3859 & 89933 \\
8 & 2901 & 59177 \\
9 & 2957 & 94758 \\
10 & 2502 & 115891 \\
11 & 370 & 12127 \\
12 & 107 & 3116 \\
13 & 2960 & 55449 \\
14 & 1015 & 15655 \\
15 & 1109 & 37657 \\
16 & 1553 & 26868 \\
17 & 1870 & 58342 \\
18 & 504 & 8980 \\
19 & 8265 & 90170 \\
20 & 14161 & 3335746 \\
21 & 3368 & 65645 \\
22 & 5887 & 94553 \\
23 & 1806 & 160684 \\
24 & 978 & 116174 \\
25 & 7045 & 253540 \\
26 & 18738 & 2466108 \\
& & \\
Total & 97512 & 10049079 \\
Force & 104573 &
\end{tabular}
\begin{tabular}{ccc} 
Sector & \begin{tabular}{c} 
Employment \\
(persons)
\end{tabular} & \begin{tabular}{c} 
Utilized gross stock \\
(millions dollars)
\end{tabular} \\
\hline 1 & 735518 & 47127 \\
2 & 118192 & 19355 \\
3 & 62383 & 35010 \\
4 & 64444 & 4912 \\
5 & 87284 & 13642 \\
6 & 305501 & 20016 \\
7 & 98423 & 1793 \\
8 & 141608 & 2531 \\
9 & 195028 & 5823 \\
10 & 204892 & 7749 \\
11 & 33323 & 2868 \\
12 & 7622 & 45, \\
13 & 182166 & 3677 \\
14 & 27410 & 764 \\
15 & 62642 & 1642 \\
16 & 177202 & 5635 \\
17 & 245841 & 21977 \\
18 & 68201 & 1028 \\
19 & 726220 & 5605 \\
20 & 1713967 & 20120 \\
21 & 433900 & 9276 \\
22 & 499772 & 53712 \\
23 & 210192 & 35659 \\
24 & 94176 & 91924 \\
25 & 522077 & 25892 \\
26 & 1003204 & 33309 \\
& & \\
Total & 8021276 & \\
Force & 9450655 & 563382 \\
Exchange & rate (\$/ECU) & 1.5646 \\
Total stock in & \\
& millions ECU & 360081 \\
& &
\end{tabular}

Table 4. Efficiency and free bilateral trade (millions ECU).
Sector

Gross output Surplus Price Europe Canada Europe Canada Europe Canada
\begin{tabular}{|c|c|c|c|c|c|c|c|}
\hline 1 & Agriculture & 174868 & 0 & 24065 & -24065 & 4.48 & 4.48 \\
\hline 2 & Mining & 0 & 89311 & -82323 & 82323 & 1.79 & 1.79 \\
\hline 3 & Petroleum \& Natural Gas & 932680 & 0 & 357380 & -10764 & 1.00 & 1.00 \\
\hline 4 & Non-metallic Minerals & 67642 & 0 & 3035 & -3035 & 2.61 & 2.61 \\
\hline 5 & Chemical Products & 165218 & 0 & 3304 & -3304 & 2.41 & 2.41 \\
\hline 6 & Metal Products & 132118 & 0 & 20558 & -20558 & 2.55 & 2.55 \\
\hline 7 & Machines & 106769 & 56230 & -37494 & 37494 & 2.75 & 2.75 \\
\hline 8 & Electrical Goods & 109653 & 0 & 5871 & -5871 & 2.76 & 2.76 \\
\hline 9 & Transportation Equipment & 163907 & 0 & 9273 & -9273 & 2.63 & 2.63 \\
\hline 10 & Food & 173458 & 53110 & -28747 & 28747 & 3.65 & 3.65 \\
\hline 11 & Beverages & 35940 & 0 & 1892 & -1892 & 1.99 & 1.99 \\
\hline 12 & Tobacco Products & 210338 & 0 & 187959 & -627 & 1.00 & 1.00 \\
\hline 13 & Textiles \& Clothing & 97577 & 0 & 3268 & -3268 & 3.61 & 3.61 \\
\hline 14 & Leather \& Footwear & 0 & 18242 & -14081 & 14081 & 4.42 & 4.42 \\
\hline 15 & Rubber \& Plastic & 53219 & 0 & 4717 & -4717 & 2.72 & 2.72 \\
\hline 16 & Wood Products & 61211 & 0 & 5686 & -5686 & 3.41 & 3.41 \\
\hline 17 & Paper \& Printing & 117120 & 0 & 11876 & -11876 & 2.89 & 2.89 \\
\hline 18 & Other Manufactures & 19374 & 0 & 2764 & -2764 & 3.14 & 3.14 \\
\hline 19 & Construction & 280495 & 32800 & 0 & 0 & 2.74 & 2.81 \\
\hline 20 & Wholesale \& Retail & 354569 & 30734 & 0 & 0 & 3.85 & 4.26 \\
\hline 21 & Lodging \& Catering & 90725 & 9009 & 0 & 0 & 3.60 & 4.27 \\
\hline 22 & Transportation & 170529 & 23708 & 0 & 0 & 2.95 & 3.25 \\
\hline 23 & Communication & 48036 & 6181 & 0 & 0 & 2.76 & 3.06 \\
\hline 24 & Utilities & 75107 & 6716 & 0 & 0 & 1.81 & 2.39 \\
\hline 25 & Finance & 448307 & 37077 & 0 & 0 & 1.78 & 1.34 \\
\hline 26 & Services & 168257 & 45051 & 0 & 0 & 8.59 & 3.48 \\
\hline \multicolumn{4}{|l|}{Total} & 479003 & 54944 & & \\
\hline \multicolumn{4}{|l|}{Labor} & 4698522 & 514669 & 0.045 & 0.054 \\
\hline \multicolumn{4}{|l|}{Capital} & 1259841 & 45879 & 0.125 & 0.127 \\
\hline \multicolumn{4}{|l|}{Total minus final demand} & 434943 & 99005 & & \\
\hline
\end{tabular}

Table 5. Domestic efficiency (millions ECU).

Gross output Surplus Price
Sector
Europe Canada Europe Canada Europe Canada
\begin{tabular}{|c|c|c|c|c|c|c|c|}
\hline 1 & Agriculture & 142148 & 14426 & 0 & 0 & 4.48 & 1.96 \\
\hline 2 & Mining & 147409 & 23788 & 0 & 12298 & 2.87 & 1.00 \\
\hline 3 & Petroleum \& Natural Gas & 880107 & 23037 & 330868 & 0 & 1.00 & 1.17 \\
\hline 4 & Non-metallic Minerals & 65861 & 4544 & 0 & 0 & 2.65 & 1.32 \\
\hline 5 & Chemical Products & 155900 & 9411 & 0 & 0 & 2.44 & 1.52 \\
\hline 6 & Metal Products & 114014 & 25078 & 0 & 0 & 2.79 & 1.27 \\
\hline 7 & Machines & 150486 & 30973 & 0 & 19059 & 2.87 & 1.00 \\
\hline 8 & Electrical Goods & 105622 & 7017 & 0 & 0 & 2.87 & 1.05 \\
\hline 9 & Transportation Equipment & 153403 & 14260 & 0 & 0 & 2.75 & 1.22 \\
\hline 10 & Food & 203269 & 16952 & 0 & 0 & 3.65 & 1.54 \\
\hline 11 & Beverages & 33918 & 2013 & 0 & 0 & 2.00 & 1.23 \\
\hline 12 & Tobacco Products & 29197 & 762 & 9205 & 0 & 1.00 & 1.22 \\
\hline 13 & Textiles \& Clothing & 92604 & 5772 & 0 & 0 & 3.61 & 1.33 \\
\hline 14 & Leather \& Footwear & 17589 & 649 & 0 & 0 & 5.11 & 1.60 \\
\hline 15 & Rubber \& Plastic & 48289 & 2893 & 0 & 0 & 2.75 & 1.39 \\
\hline 16 & Wood Products & 53690 & 7235 & 0 & 0 & 3.43 & 1.50 \\
\hline 17 & Paper \& Printing & 92567 & 13651 & 0 & 0 & 2.89 & 1.42 \\
\hline 18 & Other Manufactures & 16539 & 3275 & 0 & 0 & 3.38 & 1.31 \\
\hline 19 & Construction & 281221 & 32990 & 0 & 0 & 2.78 & 1.02 \\
\hline 20 & Wholesale \& Retail & 362341 & 29442 & 0 & 0 & 3.84 & 1.27 \\
\hline 21 & Lodging \& Catering & 90879 & 8948 & 0 & 0 & 3.60 & 1.47 \\
\hline 22 & Transportation & 171606 & 24038 & 0 & 0 & 2.96 & 1.68 \\
\hline 23 & Communication & 48182 & 6271 & 0 & 0 & 2.75 & 1.87 \\
\hline 24 & Utilities & 81716 & 6942 & 0 & 0 & 1.99 & 3.14 \\
\hline 25 & Finance & 445009 & 39087 & 0 & 0 & 1.78 & 0.55 \\
\hline 26 & Services & 166609 & 43343 & 0 & 0 & 8.53 & 1.33 \\
\hline \multicolumn{4}{|l|}{Total} & 340073 & 31357 & & \\
\hline \multicolumn{4}{|l|}{Labor} & 4678687 & 119541 & 0.045 & 0.013 \\
\hline \multicolumn{4}{|l|}{Capital} & 1237188 & 103456 & 0.123 & 0.287 \\
\hline \multicolumn{4}{|l|}{Total minus final demand} & 340073 & 31357 & & \\
\hline
\end{tabular}

Table 6. X-efficiency (millions ECU).
\begin{tabular}{|c|c|c|c|c|c|c|c|}
\hline \multicolumn{2}{|r|}{\multirow[b]{2}{*}{Sector}} & \multicolumn{2}{|l|}{Gross output} & \multicolumn{2}{|c|}{Surplus} & \multicolumn{2}{|l|}{Price} \\
\hline & & Europe & Canada & Europe & Canada & Europe & Canada \\
\hline 1 & Agriculture & 142485 & 15475 & 0 & 0 & 1.61 & 1.24 \\
\hline 2 & Mining & 175424 & 10984 & 14362 & 1489 & 1.00 & 1.00 \\
\hline 3 & Petroleum \& Natural Gas & 213682 & 27618 & 9250 & 2958 & 1.00 & 1.00 \\
\hline 4 & Non-metallic Minerals & 78361 & 5152 & 10153 & 798 & 1.00 & 1.00 \\
\hline 5 & Chemical Products & 177208 & 8937 & 18353 & 0 & 1.00 & 18.44 \\
\hline 6 & Metal Products & 115685 & 20068 & 1571 & 945 & 1.00 & 1.00 \\
\hline 7 & Machines & 150148 & 5835 & 0 & 108 & 1.02 & 1.00 \\
\hline 8 & Electrical Goods & 106052 & 7084 & 0 & 851 & 1.04 & 1.00 \\
\hline 9 & Transportation Equipment & 172842 & 18389 & 16622 & 3037 & 1.00 & 1.00 \\
\hline 10 & Food & 203787 & 19540 & 0 & 2264 & 1.30 & 1.00 \\
\hline 11 & Beverages & 40278 & 2384 & 6180 & 370 & 1.00 & 1.00 \\
\hline 12 & Tobacco Products & 24251 & 878 & 4373 & 95 & 1.00 & 1.00 \\
\hline 13 & Textiles \& Clothing & 92741 & 5710 & 0 & 0 & 1.32 & 1.35 \\
\hline 14 & Leather \& Footwear & 17604 & 628 & 0 & 0 & 1.88 & 1.21 \\
\hline 15 & Rubber \& Plastic & 49046 & 2479 & 0 & 0 & 1.01 & 7.62 \\
\hline 16 & Wood Products & 53698 & 7663 & 0 & 449 & 1.25 & 1.00 \\
\hline 17 & Paper \& Printing & 92446 & 13454 & 0 & 0 & 1.03 & 1.13 \\
\hline 18 & Other Manufactures & 16467 & 2987 & 0 & 0 & 1.22 & 1.69 \\
\hline 19 & Construction & 276621 & 32812 & 0 & 0 & 1.03 & 0.80 \\
\hline 20 & Wholesale \& Retail & 362642 & 28001 & 0 & 0 & 1.02 & 0.07 \\
\hline 21 & Lodging \& Catering & 90482 & 8657 & 0 & 0 & 1.34 & 0.33 \\
\hline 22 & Transportation & 160022 & 23149 & 0 & 0 & 1.15 & 0.35 \\
\hline 23 & Communication & 47841 & 6008 & 0 & 0 & 0.88 & 0.10 \\
\hline 24 & Utilities & 81863 & 6560 & 0 & 0 & 0.76 & 0.15 \\
\hline 25 & Finance & 439393 & 38860 & 0 & 0 & 0.63 & 0.10 \\
\hline 26 & Services & 166327 & 40880 & 0 & 0 & 2.49 & 0.83 \\
\hline \multicolumn{2}{|l|}{Total} & & & 80866 & 13362 & & \\
\hline \multicolumn{2}{|l|}{Labor} & & & 1822562 & 0 & 0.017 & 0.000 \\
\hline \multicolumn{2}{|l|}{Capital} & & & 129584 & 133519 & & \\
\hline & al minus final demand & & & 80866 & 13362 & & \\
\hline
\end{tabular}

Table 7. Factor intensities.
\begin{tabular}{|c|c|c|c|c|}
\hline Sector & \(\mathrm{k}_{\mathrm{i}} /{ }^{\text {i }}\) & \(k_{i} / r_{i}\) &  & \(k(\mathrm{I}-A)^{-1} / \imath(\mathrm{I}-A)^{-1}\) \\
\hline 1 & 0.0351 & 0.0411 & 0.0507 & 0.0443 \\
\hline 2 & 0.0654 & 0.1116 & 0.0883 & 0.0778 \\
\hline 3 & 1.6867 & 0.4090 & 0.4645 & 0.1274 \\
\hline 4 & 0.0457 & 0.0510 & 0.0702 & 0.0578 \\
\hline 5 & 0.0818 & 0.1289 & 0.0947 & 0.0890 \\
\hline 6 & 0.0233 & 0.0462 & 0.0549 & 0.0571 \\
\hline 7 & 0.0233 & 0.0103 & 0.0496 & 0.0273 \\
\hline 8 & 0.0204 & 0.0113 & 0.0461 & 0.0278 \\
\hline 9 & 0.0320 & 0.0214 & 0.0553 & 0.0345 \\
\hline 10 & 0.0463 & 0.0261 & 0.0579 & 0.0413 \\
\hline 11 & 0.0328 & 0.0634 & 0.0640 & 0.0537 \\
\hline 12 & 0.0291 & 0.0386 & 0.0560 & 0.0435 \\
\hline 13 & 0.0187 & 0.0127 & 0.0414 & 0.0222 \\
\hline 14 & 0.0154 & 0.0188 & 0.0324 & 0.0265 \\
\hline 15 & 0.0340 & 0.0123 & 0.0618 & 0.0430 \\
\hline 16 & 0.0173 & 0.0200 & 0.0428 & 0.0345 \\
\hline 17 & 0.0312 & 0.0585 & 0.0595 & 0.0578 \\
\hline 18 & 0.0178 & 0.0030 & 0.0497 & 0.0252 \\
\hline 19 & 0.0109 & 0.0048 & 0.0378 & 0.0263 \\
\hline 20 & 0.2357 & 0.0063 & 0.1907 & 0.0142 \\
\hline 21 & 0.0195 & 0.0163 & 0.0490 & 0.0239 \\
\hline 22 & 0.0161 & 0.0699 & 0.0415 & 0.0648 \\
\hline 23 & 0.0890 & 0.1123 & 0.0872 & 0.0967 \\
\hline 24 & 0.1188 & 0.6786 & 0.1170 & 0.4731 \\
\hline 25 & 0.0360 & 0.0322 & 0.0517 & 0.0404 \\
\hline 26 & 0.1316 & 0.0216 & 0.1273 & 0.0321 \\
\hline
\end{tabular}

Table 8. Observed and optimum trade between Canada and Europe.
\begin{tabular}{|c|c|c|c|c|c|}
\hline \begin{tabular}{l}
Tradable \\
Sector
\end{tabular} & \begin{tabular}{l}
Canadian \\
exports to EC \\
(million dollars)
\end{tabular} & \begin{tabular}{l}
Canadian \\
imports from EC \\
(million dollars)
\end{tabular} & \begin{tabular}{l}
European \\
net exports \\
(millions ECU)
\end{tabular} & \begin{tabular}{l}
Change in net \\
exports (table 8) \\
(millions ECU)
\end{tabular} & Optimum European net exports (millions ECU) \\
\hline 1 & 272.9 & 47.1 & -144.3 & 24065 & 23921 \\
\hline 2 & 1429.1 & 19.6 & -900.9 & -82323 & -83224 \\
\hline 3 & 344.2 & 126.1 & -139.4 & 357380 & 357241 \\
\hline 4 & 407.3 & 160.2 & -157.9 & 3035 & 2878 \\
\hline 5 & 677.7 & 492.8 & -118.2 & 3304 & 3185 \\
\hline 6 & 1257.1 & 414.5 & -538.5 & 20558 & 20019 \\
\hline 7 & 319.8 & 1145.8 & 527.9 & -37494 & -36966 \\
\hline 8 & 208.1 & 286.4 & 50.0 & 5871 & 5921 \\
\hline 9 & 254.1 & 936.4 & 436.1 & 9273 & 9709 \\
\hline 10 & 1195.1 & 255.0 & -600.9 & -28747 & -29348 \\
\hline 11 & 4.8 & 232.1 & 145.3 & 1892 & 2037 \\
\hline 12 & 49.9 & 7.5 & -27.1 & 187959 & 187932 \\
\hline 13 & 125.2 & 307.6 & 116.6 & 3268 & 3385 \\
\hline 14 & 12.5 & 105.0 & 59.1 & -14081 & -14022 \\
\hline 15 & 58.5 & 10.2 & -30.9 & 4717 & 4686 \\
\hline 16 & 706.4 & 4.0 & -448.9 & 5686 & 5237 \\
\hline 17 & 1636.1 & 240.3 & -892.1 & 11876 & 10984 \\
\hline 18 & 345.3 & 167.0 & -114.0 & 2764 & 2650 \\
\hline
\end{tabular}

Trade patterns, cooperation and grovth by

\author{
Pasquale Lucio Scandizro \({ }^{1}\)
}

\section*{1. Introduction}

The objective of this paper is to study the dynamic interdependences of econonic choices among groups of countries, in the context of a world-wide model of trade and exchange. In particular, the paper focuses on the implications of cooperative, non-cooperative and partially coordinated trade strategies for international economic policy, in a context of uncertainty and learning.

While the issues of international coordination in an uncertain environment are of obvious significance for trade policies, the recent literature on international trade has focused on endogenous grovth, learning - by - doing and dynamic spillover effects \({ }^{1}\). Oncertainty and country - level strategic behavior appear to be neglected, even though they are both potentially important sources of endogeneity and economies of scale in the process of growth.

Computable general equilibriun models (CGR's), which today appear to be the most useful practical tools to explore the quantitative effects of alternative trade policies, are an additional area of research that has neglected the question of strategic behavior, learning and uncertainty. A recent survey of these models (Scandizzo, 1992a) shows no impact of the literature on endogenous growth and almost no concern for the fact that trade occurs under uncertainty and trade regimes may be the outcome of negotiations or conflicts, rather than the consequence of unilateral choices.

These issues have received, hovever, some attention by studies on international macro-economic policies, with recent enphasis on the

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game- theoretical approach \({ }^{2}\) Even though they are generally based on simple macro-models, these studies do focus on the key issue of interdependent choices and decision-making among economic agents both within countries and across countries.

In this paper I develop a quantitative approach to study the pattern of trade and factor movement in the context of \(a\) vorld economy displaying both dynamic and stochastic features. The approach, which is based on a computable general equilibrium (CGE) model of the world economy, uses a descriptive repeated game similar to the one recently formulated by Jackson (1991). In this game three groups of countries: the "low income", the "middle income" and the "high income" interact as Bayesian players, who maximize expected national payoff and revise their expectations according to the new information collected at each round of the game.

The motivation for this approach is, first of all, to bring to bear on the issues of dynamic patterns of trade and endogenous choices the analytical potential of CGE's and, more generally, of quantitative tools using real data. Secondly, the approach aims at modelling dynamic interaction among countries and, within each country, between the decision maker and the uncertain information set that he has to face. It is this interaction that gives rise, in the context of the repeated game, to a mechanism of endogenous dynamics where Bayesian learning becomes the source of economies of scale and self-enforcing behavior.

In another paper (Scandizzo, 1992b), I examined the question of the effects of various degrees of liberalization on the "North" and the "South", also through a static general equilibrium model. In the present paper, instead, I propose to examine three broader questions: (i) which pattern of trade restrictions, comparative advantage and trade and factor movenent would prevail in the long run in the three groups of countries, (ii) which joint strategies would be selected and why, (iii) what would the likely time path followed by each country group to converge to the
long run solution.

The plan of the study is as follows. Section 2 reviews the literature on comparative versus competitive advantage, with special reference to the application of game theory to international trade. Section 3 briefly describes the features of a theoretical game formulation of a general equilibrium problem and proposes the model to be used in the sequel of the paper. Section 4.1 presents the results from the construction of the computable general equilibrium model from trade and country economic statistics and examines the features of its basic runs. Section 4.2 describes the characteristics of the Montecarlo runs of the policy game and discusses the main results obtained. Section 5 presents a summary of the results and draws some policy conclusions.

\section*{2. The Problem: comparative versus competitive advantage}

The recent literature on endogenous comparative advantage and growth presents a characterization of the pattern of world trade as derived from both accidental circumstances and strategic choice, rather than from technology and resource endowments. As a result, both development and underdevelopment appear self-validating phenomena, rather than conditions dictated by the "exogenous" circumstances surrounding the beginnings of history for each country. This seems to imply, in particular, that the inhabitants of the underdeveloped regions are themselves to blame for not having adopted the most appropriate strategies to develop a comparative advantage in the progressive sectors, or for having passively followed the trade patterns dictated by the strategic choices of other regions.

This latter conclusion, however, contains a composition error that seems to afflict all the theories on dynamic comparative advantage. In fact, just as for the imposition of a tariff, the terms of trade for a country may improve only if there is no retaliation on the part of its trade partners, protectionist measures with development objectives will be succesful only if they are not also adopted by the other countries. The neo-protectionist alternative therefore, taken to its extreme consequences, appears to lead either to a situation of little or no exchange where every country protects its own infant industries waiting for them to grow up before liberalizing trade, or to a trade war, with active and retaliatory protectionism in every market.

Table 1, which summarizes some of the features of recent studies on this topic, suggests that the main issue underlying the debate on the opportunity for strategic protectionism is the relationship between comparative advantage and competitive advantage.

Table 1

Sone characteristics of Recent Models of Dymaic Comperative Advantage
\begin{tabular}{|c|c|c|c|c|}
\hline \multirow[t]{3}{*}{Author} & \multirow[t]{3}{*}{Model Typology} & Comparative & External & Dynenic \\
\hline & & Advantage & Effects & evolution \\
\hline & & Iypology & & \\
\hline \multirow[t]{6}{*}{Sheshinski (1966)} & \multirow[t]{6}{*}{Two-sector growth model} & Long term, cumulative. & \multirow[t]{6}{*}{Learning by doing} & Mon monotonic, with possibility \\
\hline & & Depends on the & & of comparative \\
\hline & & capital/labor & & advantage reversal \\
\hline & & ratio chosen & & over time \\
\hline & & at the start. & & \\
\hline & & \begin{tabular}{l}
Dynanic \\
hysteresis
\end{tabular} & & \\
\hline \multirow[t]{4}{*}{\[
\begin{aligned}
& \text { K r'jman } \\
& \text { (1987) }
\end{aligned}
\]} & \multirow[t]{4}{*}{Game theory} & Indeterminate: & & \multirow[t]{4}{*}{None} \\
\hline & & depends on who & & \\
\hline & & plays first. & & \\
\hline & & static & & \\
\hline \multirow[t]{5}{*}{\begin{tabular}{l}
Lucas \\
(1988)
\end{tabular}} & \multirow[t]{5}{*}{Two-sector growth model} & Long term. cumulative. & \multirow[t]{5}{*}{Product Innovation} & Mon monotonic, with comparative advantage \\
\hline & & Depends on the & & reversal depending on \\
\hline & & elasticity of & & the elasticity of \\
\hline & & substitution & & substitution \\
\hline & & between goods & & \\
\hline \multirow[t]{4}{*}{Krugmen (1985)} & \multirow[t]{4}{*}{Many sector growth model} & \begin{tabular}{l}
Cumlative \\
with dynamic
\end{tabular} & \multirow[t]{4}{*}{Learning by doing} & \multirow[t]{4}{*}{Self-enforcing ("the river that creates its oun bed")} \\
\hline & & hysteresis & & \\
\hline & & depending on & & \\
\hline & & initial conditions & & \\
\hline \multirow[t]{7}{*}{\begin{tabular}{l}
Grossman \(\&\) \\
Helpman
(1989)
\end{tabular}} & \multirow[t]{7}{*}{Two sector growth model with a plurality of intermediate goods} & Long term & \multirow[t]{7}{*}{R\& \(D\) and technological progress} & The red activity \\
\hline & & cumulative & & is an instrument \\
\hline & & & & to increase \\
\hline & & & & cont imuously \\
\hline & & & & the productivity \\
\hline & & & & of the differentiated \\
\hline & & & & g000. \\
\hline \multirow[t]{4}{*}{Baunol (1986)} & \multirow[t]{4}{*}{Three sector growth model} & \multirow[t]{4}{*}{The ratio between tradeables and non tradeables is constant} & \multirow[t]{4}{*}{Only tradeables are affected by technological progress} & Balanced growth \\
\hline & & & & in terms of quantities, \\
\hline & & & & urbalanced for \\
\hline & & & & values and employment \\
\hline
\end{tabular}

Comparative advantage is a notion related to the calculation of opportunity costs and can be applied to any maximizing entity that contemplates the problem of allocating its fixed resources among competing uses. The criterion for allocation, claims the law of comparative advantage, is to undertake the activities for which the benefits are greatet compared with the benefits of the next best alternative.

From the point of view of the individual unit, therefore, comparative advantage is no more than a principle of rationality and its method of identification coincides in practice with that of cost-benefit analysis. Applied in a market where many units interact to produce different goods (corresponding to different activities), hovever, comparative advantage also implies division of labour. Under suitable assumptions of concavity of the transformation curves, each unit will specialize to some extent in those activities in which it holds a comparative advantage. Because the benefit from specialization (and trade) arises from a comparison of benefits acquired and benefits foregone, it is clearly not possible for a unit to find itself without any comparative advantage at all.

Given a pattern of comparative advantage and an ensuing pattern of specialization, however, a distributional question arises in regard to present and future distribution of the gains from trade. Both problems are related to the terms of trade, which in turn underlie any calculation of comparative advantage.

From the perspective of the individual unit, in fact, it is clearly desirable to obtain a configuration of international prices, which makes as large as possible both the present and the future share of the gains from trade. This problem however, cannot be easily solved for two main reasons. First, the simultaneous attempt by many units to tilt the terms of trade in each one's favor may be met by more or less success, but will inevitably result in a production of the overall gain from the
exchange. Without perfect information, each unit has to match the prospect of a possible gain from restricting trade in its favor with the risk of a likely loss from a reduction of total gain.

Secondly, a trade-off may arise between present and future increases in profit, welfare or other forms of payoff. Specializing in the production of a commodity without market prospects, for example, may cause the worsening of the terns of trade with a consequent loss in potential gains.

These considerations apply to all units, countries or firms alike, that operate competitively under unit-specific resource endorments. In this context the relevance of comparative advantage emerges directly from the fact that the unit is characterized by some resources, that will have some economic value, in general, no matter what the terms of trade are.

In this respect, therefore, firms, countries, regions or other competitive units differ from each other only to the extent that they are characterized by a given endowent of resources. Non sector specific management skills, for example, by definition cannot find themselves without value, because they can be employed somewhere in the market place regardless of what relative prices are. Similarly, if a country is considered as a bundle of primary factors, relative prices can only be a guide to allocate those factors to a sector rather than another. They cannot determine whether the country can or cannot stay in business.

While comparative advantage is the relevant notion for a country, with the consequence that in no case the country can be driven out of business, nevertheless "it can be driven out of some business" (Krugman, 1987). This may happen if its competitive (absolute) advantage, in terms of cost per unit of product deteriorates sufficiently vis a vis its competitors.

If a country has a comparative advantage in one sector, in order to compete with the other countries, its firms have to hold a competitive advantage, in the sense that (in a perfect market) their costs per unit of production have to be at most as high as their competitor's costs. In practice, this implies that benefit cost ratios have to be greater than one not only at shadow prices, but also at market prices after taxes. In the jargon of cost-benefit analysis, both economic and financial analysis must give positive results for the investment in any sector to be desirable and feasible.

Because a country may object to the pattern of comparative advantage on the basis of its present and future distributional implications, however, it may favor a wedge between comparative and competitive advantage. While the former is given at any moment in time, the latter may be used as an instrument to bring about a different pattern of trade and, ultimately, of distribution of trade gains.

The first set of models capable of explaining the pattern of comparative advantage as the result, rather than the cause of international trade can be traced to the theories of industrial organization developed since the 70 's. In particular, the study of the so called competitive advantage of the firm led to identify the market strategies as the most important factor of industry concentration.

In the study of competitive advantage, in fact, it is not always sufficient to identify cost reductions or quality improvements with respect to the firms that already operate in the market which one vants to enter. The possibility of exercising in an effective way one's own competitive capacities depends in fact on the success of the new firm on overcoming the so called entry barriers.

The entry barriers can be classified into two cathegories: (a)
innocent barriers, that emerge as the byproduct of a succesfull profit maximization on the part of the incumbents, and (b) Strategic barriers, that are instead erected with the specific purpose of barring the entry of new firms.

Innocent barriers give rise to two types of competitive advantage: (i) absolute ex post advantage and, (ii) asymmetric ex ante advantage. The first consists in a competitive advantage that the incumbent would maintain over the entrant, once entry is accomplished. Examples of this type of advantage are market experience, patents and know-how, advantages in costs or quality.

The asymmetric ex ante advantage consists in the asymmetry resulting from the fact that, at the monent in which the entrant examines the profitability of its investment, the incumbent has a certain amount of resources comitted unretrievably, i.e. with zero opportunity cost. This fundamental asymmetry constitutes a competitive disadvantage for the entrant because the decision of entry comes to depend on the difference between revenues and total costs, whereas the decision to remain in the market depends only on the difference between revenues and variable costs, given a certain amount of fixed costs. If the incumbent has committed a sufficient amount of resources, its exit may thus become possible only at a price so low as to render non economic the prospect of entry, even though the entrant may comand considerable competitive advantages of the ordinary sort.

The asymmetric ex ante advantage constitutes the basis for the theories of the strategic barriers, that consist of the artificial commitment of resources of the part of the incumbent in order to constitute \(a\) deterrent against the potential entrants.

The strategic asymmetry can be exploited in different ways, and is not necessarily a prerogative of the incumbent. The
entrant or another incumbent can make use of strategic asymmetry, whenever competitors that are less "strategic" or more "innocent" in their behavior.

In order to characterize the model typology arising from this approach \({ }^{3}\), consider a situation where information is perfect and communication costless. The firm exercising the strategic choices may be conveniently characterized as a monopolist, since this assumption simplifies the argument. The considerations developed, however, remain equally valid, with the appropriate variations, for an oligopolist or for a firm operating in an imperfectly competitive market.

Assume for example that the entrant identifies a single direct competitor whose profit amounts to a present value \(V_{0}\). Given a rule governing the successive interaction between the incumbent and the new firm after the entry, the incumbent and the entrant would both earn a lower present value \(V_{1}<V_{0}\). Alternatively, we can assume that the incumbent may choose, before the entry attempt, an expenditure level \(C\) that the entrant is also forced to undertake to survive. For example, we can imagine that the expenditure consists in advertising or in a discount campaign.

Table 2, which summarizes the problem in terns of the "pay-off matrix", shows the possible alternatives. From the table, which tabulates the values of profit respectively for the entrant and the incumbent, it follows that the incumbent may dissuade the entrant by spending the amount \(C<V_{1}\). Since in this case, its profit is \(V_{0}-C\), the incumbent will find convenient such a strategy whenever \(\quad V_{0}-C>V_{1}\) or, at the minimum dissuasion level \(\left(C=V_{1}\right)\), when \(V_{0}>2 V_{1}\). This condition is satisfied if the single firm that maximizes its profits in a given market space is challenged by a potential competitor with identical cost structure. In this case, in fact, Vo represents the result of
profit maximization by the only firm in a given market space, while \(2 V_{1}\) is the result of the same operation by both firms. If they are identical, they can at most hope to equate the performance of the single firm.

\section*{Table 2}
\begin{tabular}{lccc} 
New Firn & Vithout reaction & Vith reaction \\
Lnters & \(\mathbf{V}_{1}, \mathbf{V}_{1}\) & \(\mathbf{V}_{1}-\mathbf{C}\) & \(\mathbf{V}_{1}-\mathbf{C}\) \\
Does not enter & \(0, \mathbf{V}_{0}\) & 0 & \(\mathbf{V}_{0}-\mathbf{C}\)
\end{tabular}

Note: the first colum contains the nev firn's profit, while the second contains the incumbent's correspondent values.

When the new firm holds a competitive advantage, it is possible that it will find convenient to challenge the incumbent even in presence of these artificial asymmetries. It is important, however, to recognize that the possible cost or quality advantage of the entrant should be contrasted with the cost increase arising from the implicit threat of the incumbents.

These ideas have been applied to international trade in two important papers by James Brander and Barbara Spencer (1983 and 1985), where the two authors show that goverment protectionist policies may act as substitutes for strategic moves by the firas. The argument has been effectively synthesized by Paul Krugman (1987) as follows.

Assume that two countries, America and Europe, are both capable of
producing an indivisible good of high value, such as, for example, a passenger airplane of 150 seats. Moreover, assume that both countries consider this possibility with the exclusive objective to export the good produced, so that the producers' profit coincides with the national interest of both countries. Assume also that each firm (one for each country, "Boeing" and "Airbus"), faces a binary choice (to produce or not to produce).

Table \(3 A\) shows the hypothetical pay-off matrix that can be associated to the competitive game between the two countries, in the absence of government intervention.
"Boeing's" choices to produce ( P ) or not to produce ( \(N\) ) are represented by capital letters, while the corresponding choices of "Airbus" are indicated with lower case letters.

The numbers in the matrix indicate the profits of the two firms under the various alternatives (the number in the lover left corner is "Boeing's" profit, while the number in the upper right corner is "Airbus's").

Table 3 A

Hypothetical Payoff Matrix
"Airbus"


With no government intervention, the solution of the game in Table 3 A depends on initial conditions. For example, if "Boeing" commits itself to production before "Airbus" decides to do so, the result will be Pn in the NE quadrant. Onder this solution, "Boeing" will earn 100 and "Airbus" zero. To change this result, the "European" goverment will have to committ itself to subsidize "Airbus", so that it will in turn make a commitment to produce, before "Boeing" does so. For example, if the "European" government can make a commitment to pay in advance a subsidy of 10 to "Airbus", in case this company produces the airplane, independently of what "Boeing" does, the payoff matrix takes the form of Table 3B.

Under this form, it is clear that "Airbus" will always produce, since its profit is positive whether Boeing produce or not. Viceversa, "Boeing" will not find it profitable to produce. The unexpected result is that a very low subsidy, which can be entirely recuperated ex post, has allowed the "European" government to secure the potential gain from trade for "Airbus". The comparative advantage" has been created by utilizing a strategic opportunity and in turn may consolidate itself in a differential pattern of resources (e.g. know-how, market power etc.).

\section*{Table 3 B}

Payoff matrix after the European government subsidy


In more general terms, the circumstances described can be classified under the heading of "hysteresis", i.e. phenomena characterized by an asymmetry in time with respect to their causes. For these phenomena, the removal of the causes that have determined their occurrence is not sufficient to reconstitute the status "quo ante". The phenomena are (at least partially) irreversible.

In all cases of durable effects from temporary circumstances, including among the latter the economic policies that can be suspended or reversed in the course of time, the paradigm of comparative advantage loses its primacy in the theory of international trade. If becomes, al least in part, the fruit of those circumstances, and of the ensuing creation of situational asymetries, causing international trade to be shaped by a pattern that tends to validate the initial conditions that have determined its occurrence in the first place.

The innovations introduced in the models described, with respect to the pure theory of international trade, have one characteristic in common: the dependence of the equilibrium on the path followed by the economy to reach it. This characteristic, indicated with the suggestive name of "hysteresis", depends in part on the irreversibility of many real phenomena, and results from the asymmetry of the phenomena themselves with respect to time or any other variable that can "order" the choice space. The Marshallian difference between short run and long run, for example, depends on the fact that entry costs in a market for a firm are different from exit costs. The two situations: entry and exit, are one the inverse of the other from the physical, but not from the economic point of view. Another example that does not require the time variable is the difference between the amount of money necessary to compensate for a gain foregone or for an actual loss. In this case, the two events: gain foregone and loss are symmetric payoffs in the sense that they are measured by the same number. Neverthelles, they correspond to different values of the utility functions.

More generally, the situations that give origine to these asymmetries may be characterized as arising from a difference between the negation and the reversal of an event. In terms of boolean algebra, such a difference can be illustrated in the following way. Given an event \(A\), the conjuction \(U\) of this event with its negation \(\bar{A}\) ( \(A U\) non \(A\) ) yields the full set \(I\), i.e. the set formed by any event and its complement is alvays an exhaustive list of possibilities. Suppose, however, that the event \(\Delta\) has already occurred, and consider the modification determined in the set of all possible events. Two possibilities arise at this point: (i) A may be "inverted", returning the space of events to the configuration \(A\) and \(\bar{\Lambda}\), (ii) being endowed with "persistence" properties, \(A\) may not be inverted.

Indicating with \(A^{*}\) the complement to \(A\) in the "ex post" space, it is again true that \(A U A^{*}=I, \Lambda^{*} \neq \Lambda\), since the "ex ante" space has been modified by \(A\) 's occurrence. in general, therefore, given a sample space \(F\), we have:
\[
F-A \neq(F \mid A)-A
\]
i.e. the complement to \(A\) in the original space is not the same in the space modified by A's outcome, or to "undo" an event is not the same as to avoid it.

A particular class of hysteretic events is created by che capacity of the event itself to modify a given space of events by creating an entirely new one. The example utilized by Krugman (1987) to describe this phenomenon is a river that creates its own bed. In this case, the unfolding of the phenomenon creates one or more stocks of variables, that syntesize the development already occurred and, at the same time, influence the future development. The level of development depends on the stock already accumulated and this in turn depends on the development already occurred.

In this case, as before, we can say that the hysteresis (as path dependence) emerges from an asymmetry, but instead of being an a priori property of the space of the events, such an asymaetry is
caused by the self assertion capacity of the phenomenon on hand. It is the existence of a secondary circuit between the event and its occurrence, in other words, that determines the difference between the complements of the event (and/or their functions) in alternative states of the world.

From an economic point of view this second class of phenomena is particularly interesting since it tends to generate economies of scale external to the firm. The mechanism of "self-assertion" implies in fact a capacity to generate further growth as secondary effect of growth itself.

A model that can be taken to represent this class of phenomena is due once more to by Irugman (1985), who focuses on the dependence of comparative advantage on the "history" of developaent and economic policy of each country. Krugman opens his treatment asking whether and to what extent the traditional distinction between competitive advantage, which is a characteristic of the firm and comparative advantage, which is instead a characteristic of the country, may be mantained in the face of dynamic scale economies external to the firm. Onder normal circumstances, he claims, there is little foundation for the fear from the part of the entrepreneurs that temporary causes (for example, an overvalued exchange rate) may lead to a permanent loss of market shares and competitiveness for the whole country. In this case, it is clear that economists know something that business-men seem to ignore. The existence of economy-wide resource constraints, in fact, makes the resource prices responsive to a contraction or to an expansion of international market shares. Thus it is not possible that all exports of a country fall without the opening of other possibilities of market penetration elsewhere.

In spite of the apparent persuasiveness of this argument, Mrugan believes that it is incomplete. It concerns in fact an "homeostatic" vision of international competition and does not take into account the possibility of hysteresis, as a consequence of the
specialization pattern of the countries engaged in the exchange.

In order to design a model capable of analyzing this type of phenomena, Krugman resorts to a simple two-country framevork, with n tradeable goods, only one non-tradeable for each country and labour as the sole factor of production. Each tradeable production function exhibits constant returns to scale:
(1) \(\quad X_{i}(t)=A_{i}(t) L_{i}(t), \quad x_{i}(t)=a_{i}(t) l_{i}(t)\)
\[
i=1,2 \ldots n
\]
where \(X_{i}(t)\) is the \(i\)-th tradeable good in one of the two countries at time \(t, L_{i}(t)\) is the quantity of labour, \(\mathbf{A}_{i}(t)\) a productivity parameter and the low case letters denote corresponding quantities for the other country.

In each country productivity depends on an index of accumulated experience:
(2)
\[
\mathbf{A}_{\mathrm{i}}(\mathrm{t})=\mathbf{x}_{\mathrm{i}}^{\epsilon}(\mathrm{t}), \quad \mathrm{a}_{\mathrm{i}}(\mathrm{t})=\mathbf{k}_{\mathrm{i}}^{\epsilon}(\mathrm{t})
\]
\(0<\epsilon<1\)
where:
(3) \(\quad \mathbf{K}_{i}(t)=\int_{-\infty}^{t}\left[\mathbf{X}_{i}(z)+\delta \mathbf{x}_{i}(z)\right] d z\)
\[
\begin{equation*}
\mathbf{k}_{\mathrm{i}}(\mathrm{t})=\int_{-\infty}^{\mathrm{t}}\left[\delta \mathbf{x}_{\mathrm{i}}(\mathrm{z})+\mathbf{x}_{\mathrm{i}}(\mathrm{z})\right] \mathrm{d} \mathbf{z} \tag{4}
\end{equation*}
\]

Expressions (3) and (4), in particular, describe an international spill-over of experience, whose accumulation depends not only on the production of the country under consideration, but also, through the parameter \(\delta\), on the other country production. The \(\delta\) parameter, in
particular, can be interpreted as the degree of internationalization of human capital formation.

In order to close the model in the simplest possible way, Mrugman assumes also that full employment prevails in each country and that production grows at the exponential rate \(g\). He also assumes that income equals expenditure and that a constant fraction of expenditure \(\mathrm{S} \mid \mathrm{n}\) is spent on each of the n tradeable goods.

From (3) and (4), differentiating with respect to time, we obtain the relative variation of the experience indexes:
\[
\begin{equation*}
\frac{\dot{\mathbb{B}}_{i}(t)}{\overline{\mathbb{B}}_{i}(t)}=\frac{\dot{\mathbf{k}}_{i}(t)}{\mathbf{k}_{i}(t)}=\frac{\mathbf{x}_{i}(t)+\delta x_{i}(t)}{\mathbf{X}_{i}(t)}=\frac{x_{i}(t)+\delta x_{i}(t)}{\mathbf{k}_{i}(t)} \tag{5}
\end{equation*}
\]
wheere the dot denotes derivative with respect to time.

If the relative allocation of labour \(L_{i}(t) / l_{i}(t)\) is kept fixed, the variable \(\mathbb{R}_{i}(\mathrm{t}) / \mathbf{k}_{\mathrm{i}}(\mathrm{t})\) converges toward a "steady state" where, equating to zero the left hand side of (5), we obtain:


Expression (6) provides sufficient information to delimit the possibilities of international specialization in the stationary state. These possibilities can be illustrated graphycally in Figure 1 , where the curve LHS represents the left hand side of (6), and the curve RHS the right hand side. While it is clear that the stationary state of \(\mathbf{r}_{\mathbf{i}} / \mathbf{k}_{\mathbf{i}}\) is always comprised between \(\delta\) and \(1 / \delta\), the figure also shows how an increment of \(L_{i} / l_{i}\) (the dotted line) implies a higher stationary state with respect to \(\mathbb{X}_{i}\). The relative productivity \(\mathrm{A}_{\mathrm{i}} / \mathrm{w}_{\mathrm{i}}\) is thus a function of the ratio \(\mathrm{L}_{\mathrm{i}} / \mathrm{l}_{\mathrm{i}}\), and \(\mathrm{a}(0)=\delta\)
and \(a(\infty)=1 / \delta\).

At this point the author introduces two equilibrium conditions that allow further examination of comparative advantage. For the marginal industry, after ordering the \(n\) industries according to the productivity ratio \(A_{i} / a_{i}\), we can write:
(7) \(\quad \mathrm{A}_{\mathrm{i}}(\mathrm{t}) / \mathrm{a}_{\mathrm{i}}(\mathrm{t})=\mathrm{W}(\mathrm{t}) / \mathrm{w}(\mathrm{t})\)
where the right hand side represents the ratio between the wage rates paid in the two countries. Furthermore, using the expression made familiar by Dornbusch, Fisher and Samuelson (1977), we can write:
(8) \(\frac{V(t)}{W(t)}=\frac{\sigma}{1-\sigma} \frac{\bar{I}(t)}{\bar{L}(t)}\)
where \(\sigma(\mathrm{t})\) is the share of the n tradeable goods where the first country holds a comparative advantage.

In Figure 2, expression (7) is represented as the decreasing curve AA: the salary of the marginal industry is lover the higher is the share of world trade held by the country considered. Expression (8) is represented instead by the increasing straight line BB: for a given ratio between the labour force of the two countries, the wage paid by the first country with respect to that paid by the second grows with the share of the international market covered by the first country.

The dynamics of comparative advantage emerging from this model is interesting, in spite of its semplicity. For the goods produced in the first country and not produced in the second, in fact, we have that \(L_{i}(t)=S L(t) \sigma(t) n, \quad L_{i}(t)=0\), while for the others we will have \(l_{i}(t)=s l(t)(1-\sigma(t)) n, L_{i}(t)=0\). Clearly, for the
first group of goods productivity will raise more rapidly in the first than in the second country, which enjoys only an induced increment (the fraction \(\delta\) ) of the learning economies, while the opposite will occurr for the second-group of goods. This implies that the segment of \(A A\) to the left of \(\bar{\sigma}\) will raise, while the segment to the right of \(\bar{\sigma}\) will fall, so that the long term graph corresponding to AA in Figura 2 will assume the step-wise form drawn in Figure 3.

The long term pattern of comparative advantage that emerges from this characterization, therefore, is at the same time cumulative and stable. Accumulation can be seen in the progressive convergence of all industries toward the highest productivity, while stability emerges from the paradoxical result that the market share and the salary ratio remain constant over time, despite the divergent productivities between the two groups of industries.

The limit to this process of divergence between the economies of the two countries is given by the degree of internationalization \(\delta\). The larger (closer to unity) is this paraweter, the smaller the number of goods whose productivity will diverge over time. If \(\delta=1\), in particular, all goods will be produced by both countries, since the external effects, being completely internationalized, will no longer work to render comparative advantage cumulative. The increase in the degree of interationalization, therefore, restricts the interval of the possible stationary states and increases the interval of the relative wages at which a country will be competitive in one sector even without any direct experience.

In addition to this interesting, long term, cumulative property of comparative advantage, Krugman's model is useful to analyze two important phenomena related to the question of the most desirable pattern of trade. The first of these phenomena is the so called "Dutch disease", i.e. the temporary diversion of productive factors toward the exploitation of exhaustible resource. The second consists in the more monetary, but someuhat analogous phenomenon of the
temporary overvaluation of the exchange rate, that has the consequence of "pushing" resources towards the production of non tradeable goods. In both cases, the author asks, are the effects determined by these two temporary causes, equally temporary? Given the nature of the model, it does not come as a surprise that the answer to these questions is negative in both cases.

The temporary shock, in fact, in both cases is translated into an overvaluation of the exchange rate and this in turn causes a change in the \(A A\) curve that tends to validate the initial shock. The result is thus that the country will develop a pattern of specialization completely different from the one that would prevail without the shock. Presumably, the industries that resist the temporary diversion of resources are those with the highest productivity, so that the long term result will be a greater anount of specializatione in a fev goods whose initial productivity is so high that it will not be affected by the shock and will be exhalted by the ensuing development.

Can we conclude that, as for the firms, temporary shocks may determine persistent negative effects? The answer is not clear, for at least two reasons: (i) a greater degree of specialization (a smaller number of export industries) does not necessarily imply a lower level of welfare, (ii) if part of the learning effect is internalized by the firms, the result of the analysis can be entirely reversed.

The outcome of competitive resource allocation has also been studied in the context of game theory. In particular, game theory models have been applied to analize the desirability of cooperative behavior, when cooperation cannot be extended to all players. Rogoff (1985), for example, has shown that international cooperation may not be desirable if there is no cooperation within the countries among the agents determining wage rates and monetary authorities.

In a recent contribution, Matsuyama (1990) describes an infinite horizon, perfect information game between a government and a domestic firm. Instead that the usual context of a repeated game, the author builds a timing framework where irreversible consequences characterize the moves of the government, who wants to liberalize, but is willing to wait to let the firm invest, and the firm, who is willing to invest, but prefers to wait.

The scenario of this game, which suggestive of the irreversibility and the dynamic consistency problems that any sudden change of the trade regime is likely to generate, can be described as follows: in period 0 , the domestic firm enjoys monopolistic rents in the protected domestic market. In period 1 enters a new government and the game starts. The government decides whether to liberalize ( L ) or not (NL). If it choses \(L\) monopolistic rents vanish and the domestic firm is forced to play a post-entry game in a competitive market. If it choses NL, the firm decides whether to. invest (I) to prepare itself for the future liberalization, or not to invest (NI). If it choses \(I\), it will earn a lower profit in period 1, but it will be prepared to meet competition in period 2 and from this period on, its profit will be larger than it would have been without having invested earlier. In this case (the firm choses \(I\) ), the government liberalizes at the beginning of period 2 and the liberalization game ends. If the firm choses NL , on the other hand, it earn its maximum profit in period 1. The government is faced again with the alternative between \(L\) and NL at the beginning of period 2 and so on untill either it choses \(L\) or the firm choses \(I\).

In order to study the game, the author first concentrates on "Nash equilibrium", the most widely applied equilibrium concept for non cooperative games, which denotes a situation where each player choses the optimal response given the response of the other players. In the context of the game on hand, a pair of strategies ( \(g, f\) ) is a "Nash equilibrium" if g maximizes the government payoff, given that the firm has chosen \(f\), and \(f\) maximizes the firm payoff, given that the government has chosen g. A "Nash outcome" is a Nash equilibrium
at which the game ends.

After demonstrating that the pure Nash outcomes are either immediate liberalization or succesfull temporary protection for a number of periods less or equal to \(q^{*}\), the naximum number of periods the government is willing to wait, the author explores the question of credibility of the government implicit threat to liberalize. In order to do so, the author uses the concept of subgame-perfect equilibria, due to Reinhard Selten (1975). This concept is based on the idea of strenghtening the Nash equilibriun rationality by requiring that the mutual optimal response characteristic of the equilibrium strategies be true not only for the original game, but also for any subgame (i.e. any game definable as a subset of the original game).

Because sub-game perfection requires that the Nash solution remains the same under all possible subgames, it can be interpreted as a situation where no player can make a threat which he would not carry out if asked to do so.

Under these conditions, the author proceeds to show that there are \(q^{*}+1\) pure strategy subgane perfect equilibria, which are again either pure liberalization or succesfull q period protection, with \(1 \leq q \leq q^{*}\). Moreover, every pure strategy subgame-perfect equilibrium exhibits cycles with period \(q^{*}+1\). The intuition for this is that if the firm believes that the government will liberalize, it will invest. On the other hand, if the government believes that the firm will invest within \(q^{*}\) periods, it will wait. In turn, if the firm believes that the government will wait, it will not invest. But at the end of the \(q^{*}\) periods, the government will not wait. Thus, the threat of liberalization in period 2 may be made credible by the fact that, if the government fails to liberalize, it will punish itself by not liberalizing for all successive periods up to \(q^{*}\).

While there is a subgame perfect equilibrium supporting temporary protection, the author argues that both its cyclical nature and its
"bootstrap" characteristics appear unconvincing. Moreover, because of the recursive nature of the game, the equilibrium concept should require that after the nove from one of the players, the other player act consistently regardless of the time period. For example, if the firm has not liberalized in period 1, at the beginning of period 2 the government faces exactly the same situation of period 1 before the firm's decision.

The author sets aut to explore the class of stationary subgame perfect equilibria, i.e. that satisfy the requirement that each player must choose the same move when faced with the same situation. Because of the restrictiveness of this requirement, randomized strategies are allowed, the players being assumed to be risk neutral. Randomization can be justified in several ways, including its closeness to the conditions of the real world, where random events may occurr after one of the player has comitted himself to a move, slightly changhing his or the other player's payoff. In this regard, John Harsanyi (1973) has demonstrated a particularly powerful theorem of equivalence between a mixed strategy equilibrium in a game with deterministic payoffs and a pure strategy equilibrium in a game with randomly distributed payoffs.

When confronted with the possibility of chosing mixed strategies, the author finds tha in the unique mixed strategy equilibrium with the characteristics requested, the government choses \(L\) with probability decreasing with the time rate of discount of the firm, while the firm choses \(I\) with probability decreasing with the rate of discount of the government. In other vords, the governnent liberalizes with higher probability the more mopic is the firm and viceversa the firm invests with higher probability the less patient is the government. As a consequence, optimal temporary protection may succeed with a probability that is higher as the governnent is more impatient and the firm more patient.

Given that this solution is unique and squares with intuition, the author proceeds to prove that all optimal temporary protection
equilibria lack one last desirable characteristic: they are not credible in terms of the "renegotiation-proof" concepts proposed, among others, by Farrel and Maskin (1987), and Pearce (1987). In fact, on one hand, the firm cannot ask the government to renegotiate from imediate liberalization in favor of a mutually more attractive alternative, for all those solutions where credibility of optimal temporary protection depends on that of immediate liberalization. On the other hand, it can negotiate to move from immediate liberalization equilibrium to the stationary (mixed strategies) equilibrium, since its credibility does not depend on that of immediate liberalization. Such a move, hovever, would cause all the optimal temporary protection equilibria to collapse, since their credibility relies on the threat of liberalization.

Along somewhat different lines, T. Jackson (1991) constructs a game that addresses the question of liberalization by focusing on cognition, intelligence gathering and policy analysis among the countries of the Association of Southeast Asian Nations (ASEAN). The author assumes that the game is played under coditions of perfect information, where this term is interpreted as a situation where the players have perfect recall and can observe one another's moves, as in chess, and moreover, have full knowledge of the rules of the game, including one another's payoff function (Harsanyi, 1977, pp. 89-94) .

The players, identified with the six Asean countries (Singapore, Halaysia, Thailand, Indonesia, The Philippines, Brunei), are assumed to maximize national welfare, the expected payoff for each of them taking the form:
\[
\begin{equation*}
E_{t}\left[\mathbb{I}_{i}(\sigma)\right]=\sum_{k=1}^{k} \Pi_{i}\left(\sigma \mid \theta_{k}\right) P_{\sigma}^{i}\left(\theta_{k} \mid Z_{t}\right) \tag{9}
\end{equation*}
\]
where \(E_{t}\left[I_{i}(\sigma)\right]\) denotes expected payoff at time \(t\) for player \(i\) for joint strategy \(\sigma, \mathbb{I}_{i}\left(\sigma \mid \theta_{\mathbf{k}}\right)\) the payoff assigned by player i to
\(\theta_{k}\), an element of the set \(\theta=\left\{\theta_{1}, \ldots . \theta_{\mathbf{k}}\right\}\), an exhaustive list of \(\mathbb{K}\) mutually exclusive outcomes of \(\sigma\), and \(P_{\sigma}^{i}\left(\theta_{\mathbf{k}} \mid Z_{t}\right)\) is the (posterior) probability that \(\boldsymbol{\theta}_{\mathbf{k}}\) occurs, once the observation \(\mathbf{Z}_{t}\) has been collected.

Each player, therefore, faces a set of single strategies and, from the combination of all such strategies of all players a set of joint strategies. A generic element of this set is indicated with the letter \(\sigma\) and payoffs are defined as follows: .
(10) \(\mathbf{u}_{\mathbf{i}}\left(\sigma \mid \boldsymbol{\theta}_{\mathbf{k}}\right)=\boldsymbol{\theta}_{\mathbf{k}}=\frac{\mathbf{K}-\mathbf{k}}{\mathbf{K}-\mathbf{I}}\)
\[
\mathbf{k}=1,2 \ldots \mathrm{I}
\]
i.e. \(\quad \theta_{\mathbf{k}}\) is a linear function of \(\mathbf{k}\), which, letting \(\mathbb{K}=7\), implies \(\mathbb{I}_{i}\left(\sigma \mid \theta_{\mathbf{k}}\right)=1.0,0.833,0.667,0.500,0.333,0.167\), 0.000 , for \(k=1,2 \ldots 7\). In other words, given the choice of a joint strategy \(\sigma\) (among the several possible \(\sigma, \tau \ldots\) ), \(\mathbb{I}_{i}\left(\sigma \mid \theta_{k}\right)\) can be interpreted as a policy "target" with a value of 1.0 at the "bull's-eye" and decreasing values around it.

Because the game is designed to focus on the players' cognitive perspectives, the author assumes that symbolic interaction among players can be represented as a process of formation of subjective probabilities. The term \(\mathrm{P}_{\sigma}{ }_{\sigma}\left(\boldsymbol{B}_{\mathbf{k}} \mid Z_{\mathrm{t}}\right)\) denotes a subjective probability assigned by player \(i\) to the outcome \(\boldsymbol{\theta}_{\mathbf{k}}\) (i.e. over \(\boldsymbol{\theta}^{\text {), as a }}\) consequence of his interaction with the vector of observations \(Z_{t}\), on the basis of Bayes' theorem: .
(11) \(\mathrm{P}_{\sigma}^{\mathrm{i}}\left(\theta_{\mathbf{k}} \mid \mathrm{Z}_{\mathrm{t}}\right)=\frac{\mathrm{P}_{\sigma}^{\mathrm{i}}\left(\theta_{\mathbf{k}}\right) \cdot \mathrm{L}_{\sigma}^{\mathrm{i}}\left(\mathrm{Z}_{\mathrm{t}} \mid \theta_{\mathbf{k}}\right)}{\sum_{\mathbf{k}=1}^{7} \mathrm{P}_{\sigma}^{\mathrm{i}}\left(\theta_{\mathbf{k}}\right) \cdot \mathrm{L}_{\sigma}^{\mathrm{i}}\left(\mathrm{Z}_{\mathrm{t}} \mid \theta_{\mathbf{k}}\right)}\)
where \(P_{\sigma}^{\mathbf{i}}\left(\theta_{\mathbf{k}}\right)\) is i's prior probability of \(\theta_{\mathbf{k}}\) under strategy \(\sigma\) and \(L_{\sigma}^{i}\left(Z_{t} / \theta_{k}\right)\) is the likelihood of observation (information) \(Z_{t}\), assuming state of the world \(\theta_{k}\), as entertained by \(i\).

Bayes theorem allows a treatment of information gathering and interpretation as a repeated process of sampling, interpreting the inforation ("decoding") and updating the probability distribution and the expectation of the payoff that each player assigns to a joint strategy. Jackson assumes a very simple decoding structure whereby all the infornation is interpreted as either "good" or "bad" by the country gathering the intelligence. Accordingly, players are assumed to believe that all stochastic processes underlying outcones of strategy combinations are Bernoulli processes, based upon binomially disributed random variables.

If players collect information sequentially on all joint strategies (indexed by \(\sigma\) ), the likelihood function of outcome \(\boldsymbol{\theta}_{\mathbf{k}}\) under strategy \(\sigma\) for player i can be represented as:
(12) \(\mathrm{L}_{\sigma}^{\mathrm{i}}\left(\mathrm{Z}_{\mathrm{t}} \mid \theta_{\mathbf{k}}\right)=\mathrm{L}\left(\mathrm{Z}_{\mathrm{t}}=\mathrm{r}_{\sigma, \mathrm{t}}^{\mathrm{i}} \mid \theta_{\mathbf{k}}\right)=\left({\underset{\mathrm{n}}{\sigma, \mathrm{t}}}_{\mathrm{r}}^{\mathrm{i}} \boldsymbol{r}_{\mathbf{k}} \mathrm{r}_{\sigma, \mathrm{t}}^{\mathrm{i}} \cdot\left(\mathrm{I}-\theta_{\mathbf{k}}\right)^{\mathrm{n}_{\sigma, \mathrm{t}}-\mathrm{r}_{\sigma, \mathrm{t}}^{\mathrm{i}}}\right.\)

In (12), \(\mathrm{n}_{\sigma, \mathrm{t}}\) represents the sample size at time t for strategy \(\sigma\), which is assumed to be the same for all players and all joint strategies \(\left(n_{\sigma, t}=10\right)\), while \(r_{\sigma, t}^{i}\) is a sample statistic, observed by player \(i\) at time \(t\) with regard to joint strategy \(\sigma\). Statistic \(r_{\sigma, t}^{i}\) stands for national intelligence indicating the success of strategy \(\sigma\) from the point of view of the \(i\)-th country, while \(\mathbf{n}_{\sigma, \mathrm{t}^{-}} \mathrm{r}_{\sigma \mathrm{t}}^{1}\) indicates intelligence indicating failure.

In repeated sampling, as the number of positive observations \(r_{\sigma, t}^{i}\) increases, \(E_{t}\left[\Pi_{i}(\sigma)\right]\) also increases.

In order to construct the selection process, all information \(\mathbf{Z}_{\mathbf{t}}\) that can be learned about strategy, \(\sigma\) which is known to all players, is assumed to be turned into a different interpretation \(\zeta_{\sigma, t}^{i}\) by each player. Such an interpretation corresponds to the different evaluation that each player may give of the same information in terms of the perceived marginal contribution of the underlying event to national welfare of each player. Thus, a ranking according to an ordinal scale from -1 to 3 is assigned by each player to the different joint strategies: a zero ranking, for example, is assigned at time zero to conflict, which is assumed to be every player's least favorite joint strategy, a value of \(\zeta_{\sigma, t}^{i}=1\) is assigned to one of the two cooperative solutions, denoninated slow liberalization (SL), while variable ranks from -1 to 3 are assigned to the alternative cooperative solution accelerated liberalization (AL).

As a consequence of this process, the joint strategy space for each player is characterized by a complete ordering, invariant up to a monotone transformation, and we can proceed to turn the ranking index (the "interpretation") into a Bernoullian sample statistics \(r_{t}\) using the expression:
\[
\begin{equation*}
\mathrm{r}_{\sigma, \mathrm{t}}^{\mathrm{i}}=\frac{\mathbf{n}_{\sigma, \tau}}{2}+\zeta_{\sigma, \mathrm{t}}^{\mathrm{i}} \tag{13}
\end{equation*}
\]
where \(n_{\sigma, t}\), the total number of observations in a given sample, can be interpreted as historical "white noise", while \(\zeta_{\sigma, t}^{i}\) may be thought off as a noise reduction element resulting from the interpretation that the \(i\)-th player places upon information \(Z_{t}\).

Because \(\mathrm{r}_{\sigma}^{\mathrm{i}}, \mathrm{t}\) represents national intelligence showing a succesfull outcome if player i choses strategy \(\sigma\), expression (12) is
a simple way to ensure that the sample statistic \(\mathrm{r}_{\sigma, \tau}^{\mathrm{i}}\) be always smaller than the sample size \(n_{\sigma, \tau}\). Assuming that \(n_{\sigma, \tau}=10\) for all players strategies and times, expression (13) implies that \(r_{\sigma, t}^{i}\) is a compromise between 4 and 8 . At the minimum, therefore, a positive outcome will be suggested 40 percent of the times, and at the maximum 80 percent of the time. No strategy, in other words, may yield observations resulting into an interpretation of more than 40 percent failures or more than 80 percent successes. The non cooperative game resulting from this set up can be analyzed by examining all joint strategies that present the characteristics of Nash points, i.e., in the non cooperative context, are such that each player choses the strategy with the highest payoff given the choice of the other tuo players. Nash points, in fact, dominate all other points if we assume that players can choose joint, rather than single strategies.

The solution of the game formulated in this fashion turns out to be somevhat trivial, as limiting the search of solutions to the Nash points shows that AL should be excluded because is not Nash, while SL clearly doninates the non cooperative (NC) solution. The situation changes, however, once new information is taken into account and expectation are updated using the Bayesian technique. In this case both AL and SL turn out to be Nash and both dominate the NC solution without anyone of them dominating the other. Thus, a criterion of choice among Nash solutions is needed.

For this purpose the author uses the so called risk dominance criterion (Harsanyi 1977, Harsanyi and Selten 1988), which is based on the assumption that all players act and expect the others to act as Bayesians. The criterion consists in defining: (i) a principle of dominance (a point risk-dominates another if at least one player is more willing to accept the conflict pay-off than any other player proposing any other point) and, (ii) a summary of each player's risk tolerance, the so called risk limits, which measure the player's willingness to face a conflict in
sticking to a given proposal.

The author uses the direct risk limits defined as follows:
\[
\begin{align*}
\mathbf{Q}_{\mathrm{i}}(\sigma, \mathrm{t}) & =\frac{\mathbb{\Pi}_{\mathrm{i}}(\sigma)-\mathbb{\Pi}_{\mathrm{i}}(\tau)}{\mathbb{\Pi}_{\mathrm{i}}(\sigma)-\mathbb{I}_{\mathrm{i}}\left(\sigma_{\mathrm{i}}, \tau^{\mathbf{i}}\right)}  \tag{14}\\
& \text { with } \mathbb{Q}_{\mathrm{i}}(\sigma, \tau)=0 \text { if } \mathbb{\Pi}_{\mathrm{i}}(\sigma) \leq \mathbb{\square}_{\mathrm{i}}(\tau)
\end{align*}
\]
where \(\mathbb{\square}_{\mathrm{i}}(\sigma)\) is the pay-off of a strategy \(\sigma\) put forward by player \(i ; \rrbracket_{i}(\tau)\) is the payoff to \(i\) of the counter-proposal \(;\) and \(\|\left(\sigma_{i}, \quad \tau^{i}\right)\) is player's i payoff given its choice of \(\sigma^{i}\), and the other players' choice of \(\tau^{i}\) (the payoff for the conflict point).

Because the risk limit is a measure of the certain net gain that the player is willing to gamble per unit of net potential loss, one joint strategy is said to risk dominate another, if at least one player, "the decisive player", has a risk limit higher than any other player for all other points in the game. By applying this criterion, the author shows that the AL risk-dominates the SL strategy. He concludes, on the basis of the examination of the evidence for the years 1987-90, by predicting a further acceleration of trade liberalization.

Jackson's model is particularly interesting to illustrate the evolution and the many facets that the concept of comparative advantage may assume, if one is willing to give up the plain characteristics of the standard "pure" theory of international trade. First, since the definition of the preference of the players is over alternative states of the world, a country chooses a trade pattern taking into account the entire set of possible outcomes about consumption, production, trade and income distribution and not only the local (marginal) alternatives around the equilibrium point.

Secondly, the Bayesian updating creates by itself a dynamic path along which measures of comparative advantage may be revised on the basis of new information. As intelligence is accumulated on the possible states of the world and other countries behavior, patterns of trade may significantly shift in one or the other direction. The possibility of accumulation also arises, since initial beliefs may induce decisions which act as reinforcements of the beliefs that have generated them, and generate in turn further self-fulfilling decisions. As in the Irugman metaphor of the river that by flowing digs its own bed, Bayesian decision making eay induce a dynamic and cumulative patterns of trade.

Thirdly, the use of the risk limit criterion may cause dramatic changes in the concept of comparative advantage. The pattern of trade, in fact, will not depend on the opportunity cost of resources to individual countries, but will hinge upon whether a particular "decisive" player has a risk limithigher than any other player for all the other possible (NASH) equilibrium patterns. Rather than comparative, this is absolute advantage of one country, which can afford to dictate conditions to all other countries in the game.

\section*{3. A Game-Theoretic General Equilibrium Model}

The considerations developed in the previous section suggest that a general equilibrium test of dynamic comparative advantage can be attempted in the context of a world-wide non cooperative and repeated game. In particular, three features of the game structure appear specifically suited to explore the implications of endogeneity and dynamics of trade: (i) simulating strategic trade policies by different countries under incomplete information and payoffs depending on the joint strategies selected, (ii) considering dynamic accumulation of comparative advantage from strategic choices, technical progress and other economies of scale, (iii) introducing dynamics of information and learning by doing in the repeated game context.

In order to combine these features, I have built a general equilibrium model of the vorld econony through the following procedure:
(a) Estimate a social accounting matrix (SAY) of the world economy, using Vorld Bank and UNCTAD data for 1989, on the basis of the World Bank artition in Low Income, Yiddle Income, and High Income countries.

The model estimation procedure consists of two parts: (a) estimation of the Vorld SAY and, (b) estimation of the model elasticity parameters. The Vorld SAM is estimated using two different data sets: (i) Statistical data from the World Bank Vorld Development Report (1991) and, (ii) the estimates of three "representative" SAMs. The estimation procedure utilized, detailed in Appendix \(A\), consists in a combination of the fixed and the random coefficient model, and is a based on a constrained maximization algorithm. Objective of the procedure is to obtain estinates that are as close as possible to the coefficients of the "representative" SAMs and, at the same time, fit the available statistical data for the country groups examined.

Once obtained the World SAM, the model parameters (price and income elasticities) are estimated by using base estimates from other studies, and selectively changing them untill base year values are satisfactorily reproduced by the model.
(b) On the basis of the world SAY in (a), construct a computable general equilibrium (CGE) model with a dynamic feedback between investment and productive capacity in each sector.

The model used (detailed in Appendix B), is a linear computable general equilibrium structure based on the prototype developed by Norton, Scandizzo and Zimmerman (1986) and Scandizzo (1992a). The model is designed to simulate the world economy both in the short run (the "construction period"), and in the long run (the "production period"), as the interaction of three groups of national agents: the high income, the medium income and the low income countries. For each of these groups, defined according to the World Bank classification, behavioral and/or technological equations are formulated for the following agents: production sectors, capital, labour, indirect taxes, households, firms, government, financial sector. These equations form a social accounting matrix whose coefficients may change in response to a vector of policy variables that may include any exogenous variation of the model behavioral or technological variables.

The model may be organized in several blocks reflecting respectively production technology, consumers behavior, incone formation, factor markets, producers behavior, capital formation. Since the model represents the world economy, it is a closed structure and it is not necessary to represent explicitly the foreign exchange demand and supply and the formation of the exchange rate. World trade emerges directly from transactions between economic agents in different country groups, and so does factor movement if labour or capital of each country group are allowed to move to clear world markets.

All equations are linear and can be interpreted as local approximations of underlying non linear function. Alternatively, the variables can be interpreted as small variatious around base equilibrium values.

The production sector is modeled assuming fixed coefficient production functions and using the standard version of the Leontief input - output structure. Factor denand is assumed also to respect the Leontief hypothesis, so that the level of factor employment desired by the firms is a linear function of the quantities produced. Indirect taxes are also proportional, given the exogenously set tax rate, to the values produced. Because of the closed nature of the model, the commodity balance equation states that total production, for each sector, is simply the sum of internediate consumption plus final consumption, each of these variables being accounted for by economic agent (household, firns etc.) and country group.

Consumption behavior of household is modeled through linear demand functions in incomes and prices. Investnent by firms is a negative function of interest rates, vhile government and firm consumption is supposed to be ruled by fixed coefficients. Savings are generated by assuming that each institution contributes a fixed proportion of its income to capital formation, while an autonomous component of household consumption, investment by firms and government expenditure, is assumed to remain exogenous.

Income formation is assumed to arise from factor ownership as a consequence of factor endowment of each institution, the level of employment and factor prices. Both employment and factor prices are themselves determined in competitive factor markets, where demand for factors is ruled by the Leontief equations, while factor supply is assumed to be positively responsive to own factor prices, respectively in the own market when trade is restricted, or in the larger market constituted by the countries that liberalize trade. In this context competition is assumed to insure that commodity prices
equal costs, including the remuneration of capital.

Even though the equations are stated in a time independent manner, the model can be run recursively over time as a sequence of stages of "construction" and "accumulation". In the construction phase, the model is dominated by the exogenous imputs coming from autonomous demand components such as government expenditure, or from one shot policy changes, such as tax changes and removal of trade barriers. During this phase the model is driven by the exogenous changes in the sense that, given the existing production structure and factor endownent, new equilibrium values are computed that accomodate the changes. As a conseguence, each exogenous change is matched by a series of multipliers that can be considered in the Keynesian-Leontief tradition, even though they are computed in a framework of flexible relative prices.

In the accualation phase, depending on the changes occurred in the previous construction phase, factor endownents and input-output coefficients are adjusted to take into account the selective increases in productive capacity generated by investment, or other structural changes that may have occurred as a consequence of the policy actions undertaken in the constraction phase. The accumatation phase is thus driven by the structural changes depending on the previous phase and by the recurrent expenditure that may have to be created to serve the new capital. Moreover, when the model is run recursively over time, the accumation phase is also a constraction phase containing investment and policy changes for next period. Thus, each run of the model can be considered "demand" driven from current investment and policy changes and "supply" driven from past accumulation and structural changes deriving from the previous period.


Figure 1
Block diagram of model structure
(c) Simulate the following policy gane: Consider a country who is confronted with the choice between a regime of free trade and one of restricted trade (the "status" quo). Each of these choices yields a pattern of trade and a payoff depending on the choices made by the
other countries and on the outcome of a series of random factors. If the country chooses free trade, for example, and the other countries choose restricted trade, this unilateral liberalization will result on average, in a loss (with respect to the other alternatives) for all countries in question. Such a loss, however, is not entirely predetermined, since its size depends also on the outcome of a random variable that summarizes all unpredictable random factors affecting the economic process. Depending on the distribution and the size of these factors, therefore, it will not be necessarily true that in a single instance, or a in any given set of instances, the unilateral choice of free trade is necessarily harmfull to the country in question. Moreover, a country looking at the imediate consequences of its choice may not recognize the gain or the loss because it may not know what would have been the immediate consequence of alternative choices and because it will not be able to anticipate the future consequences.

Because of shortsightedness and uncertainty, each country can thus be considered to be playing a noncooperative game, cooperation being ruled out by the impossibility of knowing a priori the size of the possible gains and losses and, therefore, of calculating the necessary side payments. By assuming that the non cooperative game is played by three country groups (rich, medium and poor), however, I implicitly admit the possibility that cooperation may have been achieved within the groups, and, as a consequence, each group behaves as though it were an individual country.

Given a structure of the random payoffs, I assume that each participant to the game (each country group) picks a single strategy (free trade or restricted trade) on the basis of prior knowledge of the distribution of the payoffs associated to each possible joint strategy. Prior knowledge is constituted by some initial assumption and by what is learned by playing the game, the objective of each participant being the maximization of his expected payoff.

Each "move" from one of the players can thus be considered a way of experimenting both on the consequences of the trade regime selected and on the reaction of the other players. However, the individual player has no reason to believe that the other players act any differently from how he does. Therefore, each country group may try to learn about the behavior of the others by collecting observations on the frequencies of the others players' choices.

Each "move" of the game is thus characterized by Bayesian learning through the observation of the payoff achieved for the joint strategy resulted from everyone's choice and of the frequency of the joint strategy selected given the individual choice of a single strategy from the part of the player in question.

The process of perception, intelligence gathering and cognition is decomposed in this fashion into two distinct processes: (i) learning about the states of the vorld (outcomes of joints strategies and their distribution) and, (ii) acquiring information about likely behavior of other country groups assuming that they in turn gather information and react accordingly.

This two - fold learning process, however, is not time - neutral, since the choice of a particular trade pattern affects investment and accumulation and thus changes the configuration of payoffs and associated probabilities next period. If the game is played sequentially, therefore, the pattern of convergence to a stable solution may turn out to be cumulative and heavily dependent on initial conditions.

The simulation stages of the policy game can thus be formally summarized as follow:
- Simulate the solution of the CGE model for each group of countries for two strategies (and all the combinations thereof): (i) a strategy of restricted trade, where each country is characterized by its present level of tariffs and subsidies as
well as of barriers to factor mobilits; (ii) a liberalization strategy, where each country liberalizes its part of the exchange by removing unilaterally taxes and subsidies and/or barriers to factor movements.
- Given the simulation results for all the joint strategies in (c), perturbate the resulting payoff matrices with stochastic, uniformly or normally distributed variables, so that the payoffs for each player (households, firms, etc.) in each group of countries are scattered in an interval of occurrence, whose size depends on the size of the payoff.
- Expected payoff functions for each of the players are specified as follows:
\[
\begin{equation*}
E_{t}\left[P_{i}(S)\right]=\int_{a_{i}}^{b_{i}} P_{i}(S \mid x) d F_{s}^{i}\left(x \mid Z_{t}\right) \tag{15}
\end{equation*}
\]
where \(E_{t}\left[P_{i}(S)\right]\) is the expected payoff at time \(t\) to player \(i\) of joint strategy \(S\); \(x\) is an exogenous disturbance randonly distributed between \(a_{i}\) and \(b_{i}, F_{s}^{i}\left(x \mid Z_{t}\right)\) is the conditional distribution function assigned by player \(i\) over \(x\) at time \(t\) regarding strategy \(S\), given the observation(s) \(Z_{t}\) contributing to the player's formation of expectations about the outcome of choosing an individual strategy that may lead to the joint strategy \(S\).

Applying Bayes's theorem:
\[
\begin{equation*}
F_{s}^{i}\left(x \mid Z_{t}\right)=\frac{F_{s}^{i}(x) \cdot L_{s}^{i}\left(Z_{t} \mid x\right)}{\int_{a_{i}}^{i} L_{s}^{i}\left(Z_{t} \mid x\right) d F_{s}^{i}(x)} \tag{16}
\end{equation*}
\]
where \(F_{S}^{i}(x)\) is the prior d.f. of \(x\) and \(L_{s}^{i} \quad\left(Z_{t} \mid x\right)\) is the likelihood assigned by i to an observation \(Z_{t}\), assuming state \(x\).

International players (i.e. country groups) are assumed to know that the underlying distribution function of \(x\) is uniform or normal for every strategy \(S\). Thus, they collect sample statistics of payoffs and at each iteration update the estimated distribution in (10) and the expected payoffs in (9). National players (households, firms, and government) at this point intervene and choose the strategy that maximizes their expected payoff.

Once the strategy is chosen, its effects on productive capacity of each country group are computed. A new (stochastic) matrix of payoffs is generated and the game is played over again and again untill the choice of each group of country converges to a single strategy and thus a joint strategy prevails, or untill 50 iterations are performed, whichever comes first.
- Expected payoffs of national groups from each single strategy are estimated by weighing the expected payoffs from each joint strategy, containing the single strategy examined with the subjective probability that each country player assigns to the choice, as a result of the choice of the other country players. Starting from equally distributed joint strategies, the probability of each joint strategy is then revised using the rule:
where \(S_{g}\) is a joint strategy resulting from the simultaneous choice of the players, \(\mathrm{P}_{\mathrm{r}}^{\mathrm{i}}\left(\mathrm{S}_{\mathrm{g}} \mid \hat{S}_{\mathrm{t}}\right)\) is the conditional probability that the \(i\)-th player assigns to joint strategy \(S_{g}\), given that he
observes joint strategy \(\hat{S}_{t}, P_{r}^{i}\left(\hat{S}_{t} \mid S_{g}\right)\) is the likelihood assigned by the \(i\)-th player to the observed strategy \(\hat{S}_{t}\) assuming the state of the world is characterized by joint strategy \(S_{g}\).

In practice, equation (17) implies a revision of the prior probabilities, originally equal for each Sg , on the basis of the observed frequency, according to the rule:
\[
\begin{equation*}
P_{r}^{i}\left\{S_{g} \mid \hat{S}_{t}\right\}=\frac{P_{r}^{i}\left\{S_{g}\right\} \cdot F_{r}^{i}\left\{S_{g t}\right\}}{\sum_{g=1}^{4} F_{r}\left\{S_{g t}\right\} \cdot P_{r}^{i}\left\{S_{g}\right\}} \tag{18}
\end{equation*}
\]
where \(F_{r}\left\{S_{g t}\right\}\) is the frequency recorded at trial \(t\) of the outcome of the g-th joint strategy.
- Finally, 50 such groups of 50 iterations are run in a Montecarlo fashion and statistics of the results (payoffs, production patterns, etc.) are computed.

It is important to point out some of the innovative features that the model constructed in this fashion displays: (i) unlike the usual CGE structures, it includes a dynamic feedback between investment and capacity growth; (ii) it simulates the interaction between households, firms and the government, (iii) it focuses on the problem of cognition and information gathering on trade strategies, and simulates the ensuing interaction among countries in an uncertain environment.
4. Quantitative estimates and simulations

\subsection*{4.1 Basic features and general results}

In order to formulate a CGE model of the world economy, I start from estimating a SAM, using the data from the Vorld Bank (Vorld Development Report (1991)) and UNCTAD (Trade and Development Report (1991)) and several prototype country SAMS (see Bell, Hazell and Slade (1982), Norton, Scandizzo and Zimmerman (1986), Sadoulet and De Janvry (1990), Scandizzo (1992a)). In the resulting world-SAM three country groups: low income (LI), middle income (KI) and high income (HI), are characterized as three interdependent archetype economies, which display a mix of features respectively of poor agricultural economies (LI), semi-industrialized (MI) and industrialized countries (HI). These features, which can be read off directly from the SAM in Table 4 or the selected sumary in Table 5, are consistent with the production, consumption and trade data of the three homonimous groups of the Vorld Bank classification.

As Tables 4 and 5 show, the LI countries are characterized by a high proportion of agriculture and a low proportion of services, the main difference with the MI countries, in this respect being constituted by a slightly larger prevalence of agriculture over manufacturing. High income countries, on their part, show a much larger proportion of services and a negligible share for agriculture. Interestingly, MI countries are characterized by the lowest share of government revenue, while the \(H I\) and the LI countries show respectively the highest and the intermediate share. Labour income displays a similar share of income in all country groups. Tables 6 and 7 show the results in form of multipliers, obtained by running the model for two base: periods named respctively "construction" and "production". The "construction" period is characterized by a unit investment shock distributed over the sectors according to historical


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Table 4 (continued)
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\hline & & Agriculture & \[
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\hline P & LI & Pr. Industry & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 \\
\hline R & & Manufacturing & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.391 & 0.000 \\
\hline 0 & & Services & 0.000 & 0.000 & 0.000 & 0.024 & 0.000 & 0.000 & 0.609 & 0.000 \\
\hline D & & Agriculture & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.010 \\
\hline U & MI & Pr. Industry & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 \\
\hline C & & Manufacturing & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.977 \\
\hline I & & Services & 0.000 & 0.000 & 0.000 & 0.000 & 0.036 & 0.000 & 0.000 & 0.013 \\
\hline 1 & & Agriculture & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 \\
\hline 0 & HI & Pr. Industry & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 \\
\hline N & & Manufacturing & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 \\
\hline & & Services & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.208 & 0.000 & 0.000 \\
\hline & & Labor & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 \\
\hline F & LJ & Capital & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 \\
\hline A & & Prod. equivalents (PTE) & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 \\
\hline C & & Labor & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 \\
\hline T & MI & Capital & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 \\
\hline 0 & & Taxes (PTE) & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 \\
\hline F & & Labor & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 \\
\hline S & HI & Capital & 0.000 & 0.000 & 0.000 & 0.000 & 0.100 & 0.0000 & 0.000 & 0.000 \\
\hline & & Taxes (FTE) & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 \\
\hline & LI & Household & 0.000 & 0.000 & 0.000 & 0.050 & 0.000 & 0.000 & 0.000 & 0.000 \\
\hline & MI & Household & 0.000 & 0.000 & 0.000 & 0.000 & 0.210 & 0.000 & 0.000 & 0.000 \\
\hline 1 & HI & Household & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.290 & 0.000 & 0.000 \\
\hline N & LI & Firms & 0.000 & 0.000 & 0.000 & 0.220 & 0.000 & 0.000 & 0.000 & 0.000 \\
\hline \({ }^{1}\) & MI & Firms & 0.000 & 0.000 & 0.000 & 0.000 & 0.076 & 0.000 & 0.000 & 0.000 \\
\hline 0 & HI & Firas & 0.000 & 0.000 & 0.000 & 0.513 & 0.567 & 0.310 & 0.000 & 0.000 \\
\hline M & L! & Governaent (CSE) & 0.300 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 \\
\hline E & MI & Government (CSE) & 0.000 & 0.450 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 \\
\hline & HI & Government (CSE) & 0.000 & 0.000 & 0.450 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 \\
\hline & LI & Capital formation & 0.700 & 0.000 & 0.000 & 0.193 & 0.000 & 0.000 & 0.000 & 0.000 \\
\hline & MI & Capital formation & 0.000 & 0.550 & 0.000 & 0.000 & 0.111 & 0.000 & 0.000 & 0.000 \\
\hline & HI & Capital fornation & 0.000 & 0.000 & 0.550 & 0.000 & 0.000 & 0.192 & 0.000 & 0.000 \\
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\section*{Table 5}

\section*{Characteristics of the World SAM}
\begin{tabular}{lccc} 
INCOME SHARES & \begin{tabular}{c} 
LOW \\
INCOME \\
COUNTRIES
\end{tabular} & \begin{tabular}{c} 
MIDDLE \\
INCOME \\
COUNTRIES
\end{tabular} & \begin{tabular}{c} 
HIGH \\
INCOME \\
COUNTRIES
\end{tabular} \\
Agriculture & 0,265 & 0,237 & 0,036 \\
Manufacturing & 0,431 & 0,4 & 0,453 \\
Services & 0,237 & 0,313 & 0,472 \\
Government revenue & 0,132 & 0,065 & 0,254 \\
Labor income & 0,476 & 0,431 & 0,483
\end{tabular}
figures, while the "production" period is characterized, in addition to a similar shock, by the increase in productive capacity produced by the shock in the previous "construction" period. The model can be run recursively as a sequence of "production" periods, with each production period having also the role of investing in the productive capacity of next period.

The CGE solutions are obtained by running the model presented in Appendix B. In stylized form, this model contains, in addition to the SAM coefficients, three more sets of coefficients, which are shown in Appendix C. These coefficients are: (i) the partial derivatives of demand of consumer goods with respect to incomes and prices, (ii) the partial derivatives of factor supply with respect to factor prices and, (iii) the coefficients that relate food production per capita to prices and agricultural production levels. All these coefficients have been originally taken from other studies or directly estimated from the hystorical data available and then changed parametrically to ensure the best fit of the model to the data.

The CGE solutions are characterized by the variations of production, consumption and income levels in response to an autonomous increase in investment. More specifically, given the distribution of investment among sectors and countries in the base year, the model finds the corresponding variations in production, consumption and income levels. Expressed in normalized form (i.e. divided by total world investment), these variations represent the investment multipliers of each variable in response to a unit increase in world investment.

These "multipliers" can be used as indicators of resource allocation under alternative trade regimes. The multiplier level of a sector for a particular strategy and a given group of countries, in fact, is a measure of the "resource pull" created by that strategy toward that particular sector in the given country group. A higher multiplier level implies, coeteris

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1) In this case there is a single market for all factors, so that the multiplier refers to total factor income regardless of the country of origin.
2) In this case there is a combined market for factors of the two liberalizing country groups.
mCDEL MULTIPLIERS FOR THE STRATEGIES CONSIDEREO PRODUCTION PERICO

1), 2) See notes on Table 6.
paribus, that the sector in question will benefit more than the others from the demand boost created by the investment increase considered.

The multiplier level in the "construction period" will differ from the one in the "production period" because the latter will contain the effect of the increase in the stock of capital caused by the choice of the trade strategy in the previous (construction) period. Thus, not only the "resource pull" will be different because of the difference in backward and forward linkages characteristic of each strategy, but the difference will also be compounded or attenuated by the allocation choices made in the "construction" phase.

The joint strategy where all countries stick to the restricted trade policies (BBB) can be considered a point of reference, both because it represents a conflict solution in the game theory sense, and because it characterizes the base year. The differences between the multipliers for each joint strategy and those of the conflict solution, therefore, can be interpreted as the gains (or losses) that each sector or institution would experience as a consequence of moving from a policy of restricted trade everywhere to liberalized trade somewhere.

Tables 6, 7, presenting the multipliers for production, consumption and incomes respectively for the construction and the production period, can thus be considered payoff matrices.

Together with Table 8, which shows the differences induced in the multipliers by the previous investment phase, they can be used to analyze benefits and costs of alternative strategies for each country sector or agent. These tables show that full liberalization is overall the strategy that yields the highest aggregate benefits, but its main advantages are concentrated in developed countries.

\section*{Table 8}

MODEL MULTIPLIERS - DIFFERENCES (Production period - Construction period)

1), 2) See notes on Tible 6.

Table 9

\section*{Nash points in the G.E. solutions}

\section*{Construction period Production period}
\begin{tabular}{lcc:cr:cr:crl} 
& Construction period period \\
Production & BBA & AAA \\
Consumption & BBA & AAA \\
Households & BBA & BBA \\
Firms & BBA & ABA
\end{tabular}

This unequal distribution of the gains from trade has different consequences in the two successive phases examined. In the "construction" phase, although the solution of full liberalization does show the highest payoff for all sectors and agents, it is not a Nash point, because both LI and MI countries would have an incentive to engage in restricted trade. In the longer run (the "production" phase), on the other hand, full liberalization has both the highest payoff and is the Nash point for production and consumption, but it appears that households in other than HI countries, and firms and government in MI countries would still have un incentive to restrict trade. As a consequence, three different Nash points emerge in the longer run (Table 9) indicating a possible conflict among interest groups within the same country group.

Tables 10 and 11 , which respectively contain the multipliers and the multiplier differences for the Nash point (BBA) in the first investment phase, quantify the short run reallocative effects of liberalizing trade in the HI countries. The division of labour already prevailing in the base year situation (Table 5) would be reinforced, with a higher share of agriculture in the LI countries, and a lower one in the MI countries but with a higher level of food production in both group of countries. Compared to the strategy of restricted trade (BBB), agriculture increases everywhere and so do manufacturing and services, but the latter two increases are concentrated in the HI countries. The increases in the service sector, in particular, represent \(54.2 \%\) of the production increases in the \(H I\) countries, \(3.6 \%\) more than the restricted trade solution, while manufacturing accounts for \(38.8 \%\) of the production increases, or about 1.7 points more than the conflict solution (BBB).

A partial liberalization of world trade, led by high income countries, would thus reallocate agricultural production in favor of low and middle income countries, enhance their self-sufficiency in food consumption and would reinforce the
table 10

\section*{Production multipliers in the construction} period for the Mash solution (ta)
\begin{tabular}{lcccccr} 
Agriculture & 0.175 & 27.9 & 0.183 & 18.9 & 0.225 & 3.5 \\
Pr.Industry & 0.036 & 5.7 & 0.052 & 5.4 & 0.232 & 3.6 \\
Manufacturing & 0.251 & 40.0 & 0.426 & 43.8 & 2.519 & 38.8 \\
Services & 0.167 & 26.4 & 0.309 & 31.9 & 3.522 & 54.9 \\
Total & 0.628 & 100.0 & 0.968 & 100.0 & 6.497 & 100.0
\end{tabular}
\begin{tabular}{lll} 
Index of & 125 & 106 \\
food production & & 90 \\
pro capite \\
\((1979-81=100)\) & &
\end{tabular}

\section*{Table 11}

\section*{Production eultipliers in the construction} period: differences between the leath
solution (BEA) and the "conflict" solution (EPs)
\begin{tabular}{|c|c|c|c|c|c|c|}
\hline \multirow[t]{2}{*}{} & \multicolumn{2}{|l|}{Low income (LI) countries} & \multicolumn{2}{|l|}{Middle income (MI) countries} & \multicolumn{2}{|l|}{High income (HI) countries} \\
\hline & -.v. & \(x\) & a.v. & * & Q.v. & \% \\
\hline Agriculture & 0.011 & 33.3 & 0.001 & 33.3 & 0.002 & 3.5 \\
\hline Pr.Industry & 0.000 & 0.0 & 0.000 & 0.0 & 0.002 & 3.5 \\
\hline menufacturing & 0.002 & 66.6 & 0.001 & 33.3 & 0.017 & 29.8 \\
\hline services & 0.000 & 0.0 & 0.001 & 33.3 & 0.036 & 63.2 \\
\hline rotal & 0.003 & 100.0 & 0.003 & 100.0 & 0.057 & 100.0 \\
\hline Difference in the Index of food prod. pro capite (1979-81=100) & 9 & & 5 & & -9 & \\
\hline
\end{tabular}
pattern of international division of labour. Even though they would not liberalize, lower income countries would benefit from an increase in production of the two sectors that are "key" to progress and growth, i.e. agriculture and industry. High income countries could concentrate in manufacturing and services, where their comparative advantage lies. Yiddle income countries, on the other hand, would receive only slight benefits equally distributed in all sectors.

\subsection*{4.2 International division of labour and Bayesian playing}

One important feature of the results obtained is the fact that while in the longer run free trade may be best for everyone, during the construction phase of each investment cycle, a pattern of restricted trade in the LI and the \(M I\) countries and of free trade in the HI countries appears more likely to prevail. Whether this will occur and with what probability, however, remains to be seen. On one hand, in fact, the free trade solution remains the point with the highest aggregate payoff and the one with the highest payoff for the \(H I\) countries. On the other hand, if we assume that the payoff is not constant but undergoes possibly wide fluctuations from year-to year, what is true on average is not true in each period. Thus, the possibility of repeating the choice of the trade strategy over and over may in principle give rise to more than one pattern of international trade.

Because Bayesian learning gives rise to a non linear accumulation of information, furthermore, repeated choices of trade strategies within a stochastic environment may cause a pattern of trade that tends to perpetuate itself thereby validating its own choice. This phenomenon, which is similar to the one hypothesized by Krugan (1985) in a non-stochastic context, may arise because any learning mechanism based on "picking winners", once chosen a suitable strategy, that appears attractive on the basis of present knowledge, may neglect to update the information on the alternatives, thus validating the original choice.

In the case of the uniform distribution, this mechanism appears to be particularly effective because the Bayesian behaviour illustrated by equations (13), (14) and (15) is based on the extraction of a single sufficient statistic from the observations. In fact, given a random sample \(Z_{1} \ldots . Z_{t}\) from the uniform distribution over the interval (a,b), the conditional
probability distribution function (p.d.f.) of any single observation will depend on the values of the observations \(Z_{1} \ldots Z_{t}\) only through the bi-dimensional vector statistic:
\(\left[\min \left(Z_{1} \ldots Z_{t}\right) ; \max \left(Z_{1} \ldots Z_{t}\right)\right]\).

More specifically, assume that \(Z_{1} \ldots Z_{t}\) is a random sample from the uniform distribution on the interval \((0, C)\), where the value of \(C\) is unknown. For any given value \(c\) of \(C\) such that \(c>0\), the conditional p.d.f. \(f(. / c)\) of any single observation Zj is specified by the equation:
(19) \(f(Z \mid c)=\left\lvert\, \begin{array}{ll}\frac{1}{c} & \text { for } Z<c \\ 0 & \text { otherwise }\end{array}\right.\)

Assuming, as in our experiments, that the sample space is the set of positive numbers, the joint p.d.f. \(f(. / c)\) of \(Z_{1}, \ldots . Z_{t}\), where \(C=c(c>0)\), is as follows:
\[
f_{t}\left(Z_{1} \ldots z_{t} \mid c\right)=\left\lvert\, \begin{array}{ll}
\frac{1}{c^{t}} & \text { for } \max \left\{z_{1} \ldots z_{t}\right\}<c  \tag{20}\\
0 & \text { otherwise }
\end{array}\right.
\]

Under these conditions, consider the choice of a joint strategy. In the first trial, such a choice may occur only because of the expected values of the single strategies chosen by the different players. In order to be abandoned, however, it is necessary that at least one player finds its expected value from the joint strategy decreasing. But this can never happen since the sufficient statistic \(\max \left(Z_{1} \ldots Z_{t}\right)\) can only be updated upward! Thus, once chosen, a joint strategy will perpetuate itself.

If both the lower and the upper bound of the uniform distribution are unknown, the situation changes because the sufficient statistic \(\left\{\min \left(Z_{1} \ldots Z_{t}\right) ; \max \left(Z_{1} \ldots Z_{t}\right)\right\}\) is amenable to both downward and upward revisions. Consider the expression for the expected value of the single strategy \(S^{h}\) selected by player i :

The i-th player will switch to the other single strategy only if, in the next trial ( \(\mathrm{t}+1\) ), the following condition occurs:
\[
\begin{align*}
& \left|\Delta E_{t}\left[P_{i}\left(S_{g}\right)\right]\right|>\frac{E_{i}\left(S^{h}\right)-E_{i}\left(S^{\mathbf{k}}\right)}{P_{r}\left\{S_{g} \mid \hat{S}_{t}\right\}}+  \tag{22}\\
& \frac{1}{P_{r}\left\{S_{g} \mid \hat{S}_{t}\right\}}\left({ }_{g} \neq \dot{E} E_{t}\left[P_{i}\left(S_{g}\right)\right] \Delta P_{r}\left\{S_{g}, \mid \hat{S}_{t}\right\}\right.
\end{align*}
\]
where \(\Delta E\) indicates the variation of the expected payoff and \(\Delta P_{r}\) the variation of the probability from one trial to the other.

Expression (22) states the condition that, in order to change his choice of the single strategy \(S^{h}\), the i-th player will have to change his expectation about the payoff of the joint strategy realized by an amount made up by two additive components: (a) the ratio between the prior advantage of \(S^{h}\) over \(S^{k}\) divided by the posterior probability of joint strategy \(S_{g}\), (b) minus the weighted sum of the variations of the probabilities of the other joint strategies \(\left(g^{\prime} \neq g\right)\) divided again by the probability of \(S_{g}\).

If no change has occurred in the previous trial, the second term is zero. As for the first term, its size is larger in the
early trials, since \(P_{r} \quad\left\{S_{g} \mid S_{t}\right\}\) at the beginning is close to \(1 / 4\). Thus, for \(t\) small, while the probability of revising the lower bound of the uniform distribution is larger, the amount required to cause the change is greater. As \(t\) grows large, on the other hand, the opposite occurs, since the frequency of the joint strategy selected grows, while the probability of observing a value lower than the minimum (i.e. the probability that \(a\) value lower than the minimum has not been observed already) declines.

Tables 12 and 13 show the results of a Montecarlo experiment performed applying the methodology described for the case where the infornation at the players' disposal is exclusively on the short run effects of investnent and expected payoffs are perturbed by a random disturbance with a uniform distribution within a given interval.

Table 12, which presents the frequency of choice by strategy for each of the 50 sets of 50 trials, and the related average payoffs, lends itself to two main considerations. First, convergence to the Nash solution is obtained in almost \(32 \%\) of all trials and commands a simple majority in 22 out of the 50 trial sets. In purely probabilistic terms, therefore, if information on the demand effects of investment prevails, as it is likely, over information on the supply effects, we should expect a tendence toward the persistence of international trade restrictions in LI and \(M I\) countries and toward free trade in HI countries.

Second, in several cases, convergence to the Nash solution was not obtained, while other joint strategies seemed to prevail. Although such a prevalence is of unstable nature, because of the incentive for some of the players to adopt alternatives, the results clearly show a tendence to depart from a suitable learning path in many cases. In particular, the possibility of cumulative self-validating processes appears to be confirmed for certain strategies (BAA and BBB) with quasi-Nash characteristics. For example, in the 6 - th, the 7 - th, and 16 th set of trials the


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Table 13

FREQUENCY OF SINGLE STRATEGIES AND AVERAGE PAY-OFFS (Uniform distribution, construction period)
\begin{tabular}{|c|c|c|c|}
\hline & \begin{tabular}{l}
FREQUENCY OF ST COOPERATIVE \\
(a)
\end{tabular} & \begin{tabular}{l}
RATEGIES CHOSEN NON-COOPERATIVE \\
(b)
\end{tabular} & AVERAGE PAYOFF \\
\hline LOW INCOME COUNTRIES & \(23.72 \%\) & \(76.28 \%\) & . 349 \\
\hline MIDDLE INCOME COUNTRIES & \(23.40 \%\) & 76.60\% & . 718 \\
\hline HIGH INCOME COUNTRIES & \(51.44 \%\) & \(48.56 \%\) & 3.221 \\
\hline
\end{tabular}
players' choice was 50 times over 50 trials joint strategy BBB. While the Nash point BAA tends to dominate the other strategies on average, therefore, the presence of the stochastic elenent gives significant possibilities to several suitable alternatives of restricted trade. The conflict solution (BBB), which is assumed to prevail in the base year, in particular, is chosen with a respectable 26.44\% frequency.

In this context, the free trade alternative does not appear to hold many chances of success (2.36\% total score over the 2500 trials), nor does it display any possibilities of cumulative self-assertiveness.

As Table 13 shows, the single strategies chosen by the players over the entire experiment reflect the influence of the expected payoffs, but are themselves affected by the randomness of the outocomes and by the information learning process. Thus, evcis though non liberalizing strategies are almost always dominant for LI and MI countries in terms of expected payoffs, they are chosen only about \(75 \%\) and \(77 \%\) of the time respectively. Similarly, HI countries choose their dominant, liberalizing strategy only about \(51 \%\) of the time.

Tables 14 and 15 present a second set of Yontecarlo experiments, where \(I\) have assumed that expected payoffs are perturbed by a normally, rather than unifornly, distributed random variable. Furthermore, in addition to simulating the short run effects of investment, the longer run consequences are also taken into account by computing the increases in the productive capacity of each sector determined by the chosen investment pattern (see Appendix A). Moreover, the choice of the pattern of trade (i.e. the joint strategy) at the construction phase is assumed to determine the pattern of increase in productive capacity in the longer run, thus linking the two phases to each other and providing the model with a chain of dynamic feedbacks.

Table 14
\begin{tabular}{|c|c|c|c|c|c|c|c|c|c|c|c|}
\hline KIA SET & TECPRLO & \[
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& \text { NT STRATE: }
\end{aligned}
\] & BAYESIO Ifrea & PLAY FOP cy of ch &  & \begin{tabular}{l}
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\end{tabular} & \[
\begin{aligned}
& \text { PERI00" } \\
& \text { set) }
\end{aligned}
\] & \multicolumn{4}{|c|}{AVERAGE FAITFFS} \\
\hline \multirow[t]{2}{*}{THIAL SEI} & & & & & & & & & AYES & ( PAYOP & \\
\hline & AFA & A AB & H6A & A88 & 8AA & 886 & GAES & 888 & L.l & A.l. & H.1. \\
\hline 1 & 28 & 1 & 9 & 3 & \(b\) & 0 & 3 & 0 & 0.247 & 0.648 & 4.034 \\
\hline 2 & 0 & 0 & 0 & 0 & 10 & 17 & 17 & 0 & 0.306 & 0.714 & 4,875 \\
\hline 3 & 0 & 5 & 0 & 0 & 4 & 23 & 4 & 14 & 0.356 & 0.639 & 3.289 \\
\hline 4 & 0 & 4 & 0 & 0 & 10 & 20 & 5 & 5 & 0.399 & 0.792 & 5.148 \\
\hline 5 & 0 & 0 & 0 & 0 & 2 & 17 & 5 & 26 & 0.342 & 0.825 & 4.465 \\
\hline 8 & 28 & 14 & 4 & 0 & 4 & 0 & 0 & 0 & 0.293 & 0.609 & 3.909 \\
\hline 7 & 0 & 0 & 1 & 9 & 0 & 4 & 14 & 22 & 0.326 & 0.493 & 4.314 \\
\hline 8 & 0 & 0 & 28 & 7 & 0 & 0 & 0 & 15 & 0.323 & 0.842 & 4.348 \\
\hline 9 & 0 & 0 & 0 & 15 & 0 & 1 & 27 & 7 & 0.317 & 0.766 & 4.300 \\
\hline 10 & 9 & 0 & 2 & 2 & 0 & 0 & 15 & 22 & 0.284 & 0.668 & 3.791 \\
\hline 11 & 0 & 0 & 3 & 14 & 17 & 8 & 0 & 8 & 0.372 & 0.558 & 4.054 \\
\hline 12 & 27 & 8 & 1 & 8 & 0 & 0 & 6 & 0 & 0.291 & 0.517 & 4.769 \\
\hline 13 & 0 & 0 & 0 & 4 & 0 & 24 & 0 & 22 & 0.346 & 0.785 & 5.090 \\
\hline 14 & 0 & 36 & 0 & 7 & 1 & 3 & 3 & 0 & 0.358 & 0.850 & 5.269 \\
\hline 15 & 0 & 0 & 0 & 5 & 0 & 0 & 31 & 14 & 0.478 & 0.782 & 4.446 \\
\hline 16 & 0 & 0 & 40 & 4 & 0 & 6 & 0 & 0 & 0.309 & 0.848 & 4.510 \\
\hline 17 & 0 & 0 & 19 & 0 & 0 & 31 & 0 & 0 & 0.298 & 0.805 & 4.605 \\
\hline 18 & 3 & 0 & 0 & 0 & 5 & 13 & 1 & 25 & 0.352 & 0.638 & 4.12 J \\
\hline 19 & 20 & 27 & 0 & 2 & 0 & 0 & 1 & 0 & 0.35 & 0.625 & 4.935 \\
\hline 20 & 21 & 18 & 0 & 0 & 4 & 5 & 2 & 0 & 0.363 & 0.666 & 4.899 \\
\hline 21 & 0 & 0 & 21 & 4 & 0 & 16 & 0 & 9 & 0.210 & 0.701 & 4.806 \\
\hline 22 & 4 & 0 & 35 & 0 & 0 & 11 & 0 & 0 & 0.325 & 0.738 & 4.412 \\
\hline 23 & 0 & 0 & 0 & 0 & 29 & 18 & 3 & 0 & 0.438 & 0.535 & 3.476 \\
\hline 24 & 0 & 0 & 0 & 0 & 26 & 24 & 0 & 0 & 0.396 & 0.850 & 3.930 \\
\hline 25 & 0 & 0 & 11 & 0 & 5 & 26 & 0 & 8 & 0.331 & 0.628 & 3.655 \\
\hline 26 & 0 & 0 & 0 & 43 & 0 & 0 & 0 & 7 & 0.318 & 0.841 & 4.345 \\
\hline 27 & 11 & 9 & 9 & 0 & 12 & 9 & 0 & 0 & 0.387 & 0.557 & 5.878 \\
\hline 28 & 3 & 9 & 4 & 0 & 0 & 18 & 16 & 0 & 0.362 & 0.850 & 3.850 \\
\hline 29 & 0 & 0 & 1 & 0 & 1 & 27 & 5 & 16 & 0.426 & 0.561 & 4.417 \\
\hline 30 & 0 & 0 & 11 & 15 & 1 & 10 & 20 & 3 & 0.303 & 0.58 & 5.117 \\
\hline 31 & 2 & 0 & 22 & 1 & 0 & 25 & 0 & 0 & 0.35 & 0.913 & 3.051 \\
\hline 32 & 0 & 0 & 28 & 0 & 2 & 12 & 8 & 0 & 0.315 & 0.737 & 3.567 \\
\hline 3 & 0 & 0 & 1 & 8 & 0 & 18 & 0 & 23 & 0.411 & 0.980 & 3.520 \\
\hline 34 & 0 & 0 & 9 & 1 & 1 & 39 & 0 & 0 & 0.374 & 0.741 & 3.813 \\
\hline 35 & 0 & 0 & 11 & 0 & 4 & 19 & 16 & 0 & 0.350 & 0.721 & 4.877 \\
\hline 36 & 3 & 8 & 0 & 26 & 0 & 0 & 2 & 11 & 0.417 & 0.529 & 4.016 \\
\hline 37 & 0 & 8 & 0 & 0 & 32 & 0 & 10 & 0 & 0.361 & 0.612 & 5.252 \\
\hline 38 & 0 & 0 & 0 & 44 & 0 & 0 & 0 & 6 & 0.386 & 0.622 & 4.288 \\
\hline 39 & 15 & 21 & 0 & 14 & 0 & 0 & 0 & 0 & 0.301 & 0.627 & 4.806 \\
\hline 40 & 25 & 1 & 2 & 0 & 22 & 0 & 0 & 0 & 0.258 & 0.526 & 5.836 \\
\hline 41 & 0 & 0 & 0 & 0 & 9 & 13 & 26 & 2 & 0.398 & 0.675 & 4.554 \\
\hline 42 & 0 & 0 & 0 & 0 & 0 & 38 & 0 & 22 & 0.491 & 0.851 & 4.620 \\
\hline 43 & 0 & 0 & 1 & 0 & 13 & 32 & 4 & 0 & 0.348 & 0.620 & 5.127 \\
\hline 44 & 2 & 1 & 0 & 1 & 24 & 18 & 1 & 3 & 0.306 & 0.688 & 3.552 \\
\hline 45 & 0 & 5 & 0 & 14 & 0 & 4 & 2 & 25 & 0.331 & 0.750 & 4.310 \\
\hline 46 & 0 & 0 & 0 & 4 & 0 & 16 & 0 & 30 & 0.370 & 0.813 & 4.461 \\
\hline 47 & 0 & 20 & 4 & 13 & 0 & 0 & 9 & 4 & 0.345 & 0.507 & 4.345 \\
\hline 48 & 0 & 0 & 38 & 0 & 0 & 10 & 0 & 2 & 0.297 & 0.768 & 4.826 \\
\hline 49 & 21 & 13 & 0 & 4 & 0 & 7 & 0 & 5 & 0.300 & 0.725 & 2.95 \\
\hline 50 & 0 & 0 & 27 & 0 & 0 & 17 & 0 & 6 & 0.257 & 0.626 & 5.408 \\
\hline & 9.12\% & 8.34 & \(13.68 \%\) & \(10.88 \%\) & 9.76\% & 23.802 & 10.36\% & 14.48\% & 0.343 & 0.699 & 4.402 \\
\hline
\end{tabular}
\begin{tabular}{|c|c|c|c|c|c|c|c|c|c|c|c|}
\hline \multicolumn{12}{|l|}{\multirow[t]{2}{*}{}} \\
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\hline \multirow[t]{2}{*}{\[
\begin{gathered}
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\text { No }
\end{gathered}
\]} & & & & & & & & & \multicolumn{3}{|l|}{AVENAGE F'AITFF} \\
\hline & dad & dab & 20.3 & 36 b & bai & buz & Oab & bub & 1 & 2 & 3 \\
\hline i & 0 & 9 & 0 & 4 & 15 & 2 & 12 & 17 & . 578 & 1.023 & 6.709 \\
\hline 2 & 0 & 0 & \({ }^{\boldsymbol{S}}\) & 11 & 0 & 0 & 0 & 14 & . 474 & 1.037 & 6.205 \\
\hline 3 & 0 & 1 & 0 & 19 & 0 & 2 & 1 & 27 & . 694 & 1.000 & 8.167 \\
\hline 4 & 0 & 25 & 1 & 0 & 1 & 2 & 2 & 13 & . 617 & 1.166 & 7.418 \\
\hline 5 & 0 & 0 & 3 & 2 & 1 & 14 & 0 & 10 & .47 & 1.191 & 5.941 \\
\hline 5 & 0 & 18 & 0 & 0 & 1 & 12 & 1 & 12 & . 519 & 1.431 & 6.141 \\
\hline 7 & 0 & 0 & 0 & 0 & 0 & V & 31 & 19 & . 620 & 1.295 & 0.614 \\
\hline 8 & 0 & 0 & 3 & S & 0 & 0 & 0 & 17 & . 588 & 1.230 & 7.757 \\
\hline 9 & 0 & 31 & 0 & 13 & 0 & \(\dot{0}\) & 0 & 3 & . 647 & 1.204 & 9.063 \\
\hline 10 & 0 & 0 & 0 & 17 & \(!\) & 4 & 1 & 27 & . 65 & 1.207 & 6.262 \\
\hline 11 & 0 & 0 & 0 & 0 & 11 & j & 11 & 25 & . 693 & 1.231 & 6.951 \\
\hline 12 & 0 & 0 & 0 & 0 & 0 & 1 & 32 & 17 & . 672 & . 922 & 7.900 \\
\hline 13 & 25 & 1 & 19 & 0 & 0 & 1 & 2 & 2 & . 117 & 1.194 & 6.682 \\
\hline 14 & 0 & 0 & 2 & 0 & 24 & 16 & 0 & 8 & . 65 & 1.100 & 7.626 \\
\hline 15 & 0 & 0 & 1 & 19 & 3 & 3 & 1 & 23 & . \(50 \%\) & 1.317 & 6.884 \\
\hline 16 & 1 & 1 & 2 & 2 & 2 & 8 & 13 & 21 & . 688 & 1.127 & 7.379 \\
\hline \(\Gamma\) & 0 & 0 & 0 & 0 & 23 & 27 & 0 & 0 & . 674 & 1.19 & 7.702 \\
\hline 18 & 0 & 0 & 15 & 28 & 0 & 0 & 0 & 7 & . 514 & 1.223 & 7.810 \\
\hline 19 & 19 & 21 & 1 & 2 & 2 & 2 & 2 & 1 & . 384 & 1.221 & 7.924 \\
\hline 20 & 6 & 3 & 2 & 0 & 6 & 1 & 19 & 13 & . 499 & 1.185 & 7.124 \\
\hline 21 & 9 & 0 & 7 & 0 & 1 & 8 & 8 & 17 & . 534 & 1.252 & 6.587 \\
\hline 22 & 0 & 14 & 1 & 25 & 1 & 1 & 3 & 5 & . 428 & 1.133 & 7.705 \\
\hline 23 & 0 & 0 & 0 & 0 & 5 & 1 & 31 & 13 & . 699 & 1.218 & 6.501 \\
\hline 24 & 8 & 19 & 1 & 2 & 0 & 0 & 0 & 0 & . 516 & . 951 & 7.572 \\
\hline 25 & 0 & 0 & 15 & 1 & 8 & \% & 0 & 1 & . 576 & 1.046 & 7.432 \\
\hline 26 & 0 & 3 & 0 & 3 & 0 & 6 & 28 & 10 & . 589 & 1.049 & 7.212 \\
\hline 27 & 0 & 0 & 0 & 0 & 31 & 8 & 0 & 11 & . 587 & 1.218 & 9.013 \\
\hline 28 & 0 & 0 & 0 & 5 & 1 & 16 & 1 & 27 & . 658 & 1.152 & 8.604 \\
\hline 29 & 4 & 2 & 1 & 1 & 8 & 28 & 4 & - 2 & . 687 & 1.004 & 8.119 \\
\hline 30 & 3 & 0 & 4 & 2 & 4 & 12 & 23 & 2 & . 666 & 1.072 & 7.011 \\
\hline 31 & 28 & 0 & 11 & 9 & 0 & 1 & 0 & 1 & . 492 & 1.088 & 7.858 \\
\hline 32 & 0 & 0 & 0 & 38 & 0 & 1 & 0 & 11 & . 611 & 1.359 & 7.638 \\
\hline 37 & 0 & j & 1 & 11 & 1 & 1 & 20 & 13 & . 566 & 1.158 & 7.971 \\
\hline 34 & 0 & 0 & 3 & 7 & 25 & 5 & 3 & 9 & . 403 & 1.124 & 6.575 \\
\hline 35 & 0 & 0 & 0 & 0 & 0 & 0 & 31 & 19 & . 599 & 1.103 & 6.838 \\
\hline 30 & 0 & 16 & 0 & 0 & 0 & 1 & 25 & 8 & . 521 & 1.120 & 8.091 \\
\hline 37 & 6 & 0 & 0 & 0 & 13 & 0 & 25 & 6 & . 618 & . 922 & 6.013 \\
\hline 39 & 39 & 0 & 1 & 7 & 1 & 0 & 0 & 2 & . 517 & 1.028 & 8.75 \\
\hline 39 & 0 & 0 & 9 & 0 & 0 & 41 & 0 & 0 & . 53 & 1.208 & 7.381 \\
\hline 40 & 5 & 1 & 16 & 7 & 2 & 2 & 1 & 16 & . 551 & 1.121 & 7.72 \\
\hline 41 & 2 & 3 & 5 & 0 & 4 & 5 & 17 & 14 & . 522 & 1.560 & 8.038 \\
\hline 42 & 0 & 1 & 0 & 1 & 0 & 8 & 3 & 37 & . 600 & 1.218 & 7.990 \\
\hline 43 & 0 & 0 & 0 & v & 0 & 24 & 0 & 26 & . 606 & 1.149 & 8.503 \\
\hline 4 & 20 & 0 & 3 & 4 & 20 & 0 & 0 & 3 & . 592 & . 831 & 7.123 \\
\hline 45 & 0 & 0 & 14 & 3 & 0 & b & 1 & 26 & . 466 & 1.294 & 7.251 \\
\hline 40 & 0 & 0 & 26 & 4 & 0 & \(j\) & 0 & 17 & . 486 & 1.217 & 8.118 \\
\hline 47 & 0 & 8 & \(\hat{*}\) & 2 & 0 & 1 & 28 & 11 & . 542 & 1.012 & 7.616 \\
\hline 48 & 1 & 2 & 15 & 8 & 1 & 2 & 20 & 1 & . 418 & 1.133 & 6.710 \\
\hline 49 & 1 & 3 & 1 & 1 & 1 & 9 & 8 & 26 & . 566 & 1.163 & 7.014 \\
\hline 50 & 0 & 0 & 0 & 0 & 0 & 3 & 1 & 14 & . 527 & 1.085 & 6.162 \\
\hline & \(7.08 \%\) & \(7.16{ }^{4}\) & \(9.00 \%\) & 12.92\% & 8.682 & 13.842 & 16.362 & 24.962 & . 566 & 1.150 & 7.402 \\
\hline
\end{tabular}

The results for both periods are, in reality, somewhat disconcerting. While the uniform distribution displayed a tendency to cause "bang-bang" behavior, with choices immediately concentrated in one solution, normally distributed disturbances appear to have the opposite characteristic of wandering somewhat among different strategies before locking in a particular solution.

Both for the construction and the production period, hovever, the most disconcerting result appears to be the demise of the Nash solution. To be sure, in the construction phase, the Nash point BBA manages to command a relative majority, but at around 24\%, such a majority does not appear to offer any assurance that the world will converge to a stable solution, even in the presence of a cumulative learning mechanism about the payoff distribution. For the production phase, moreover, the Nash point is not even a joint strategy preferred most of the time, in the relative sense, by all players. The conflict solution BBB, instead, is the most popular one, even though players appear to choose it often in combination with the Nash solution or with other points.

Unlike the uniform distribution case, the free trade solution dominates the players' choices in several trial sets and overall commands a significant \(9,12 \%\) of choices. While this is still a lov frequency compared to the other, globally less advantageous joint strategies, this result appears more encouraging than the earlier one.

\section*{5. Conclusions and Policy Lmplications}

Rather than by a continuous variation of trade restrictions and resource allocation, policy reform can be characterized as the switching from one trade regime to another, thereby involving a choice among a limited number of alternative combinations of trade strategies.

In this paper a computable general equilibrium model has been used to generate alternative patterns of economic activity, corresponding to different combinations of policy regines of liberalized and restricted trade. The use of a game theory framework has shown that the usual comparative advantage principles may be inadequate to identify meaningfull scenarios for prediction or policy recomendation. The distribution of gains from trade both within and across countries, in fact, and the lack of inforation on the likely outcomes of the different policy changes may prevent countries from liberalizing trade, even though this policy does insure that aggregate welfare is maximized.

The simulation runs with the estimated model have shown that, in spite of the aggregate superiority of the free trade scenario, a joint strategy of partial liberalization constitutes an a priori superior policy set from the Nash point of view of self-enforcing or bargaining equilibria. Because high incone countries appear to be the main beneficiaries of trade liberalization both in the short and in the long run, it seens fair to recommend that they unilaterally liberalize trade and remove all relative price distortions within their economies. Viceversa, the model suggests that low and middle income countries should not liberalize in the short run, but could move to gradually eliminate their own barriers to trade in a longer period of time, once the beneficial impact of the first round of liberalization would begin to display their impact on the overall
reallocation of productive capacity.

While these conclusions are clear from a normative point of view, the use of a Bayesian learning mechanism combined with the general equilibrium model yields results that give only little hope that the solution recomended will be spontaneously reached by the countries involved in the international policy game.

A first attempt at simulating country choices within a Bayesian game-theoretic framework with a uniform distribution of payoffs did produce results showing a clear tendency to choose the Nash solution in a large majority of cases. The use of a normal distribution, which appears as a more likely candidate to represent the conditions of uncertainty in the market, however, suggests otherwise. Only in a relatively small segment of total strategy space, in fact, did the choices made converge toward the Nash equilibrium. Moreover, while the number of Nash choicus constitute a relative majority among the joint strategies available in the short run, the long run exhibits a clear preference for the conflict solution.

Finally, the model developed incorporates the suggestion made in the recent trade literature that policies may be cumulative and become self-enforcing via accumulation mechanisms of various types. The Bayesian learning mechanism appears to do that by tying successive choices to payoff estimation and viceversa by concentrating on learning about payoff distributions for choices which originally happen to be made by chance.

Within this context, a policy of "picking winners" is naturally derived by the fact that each strategy is chosen on the basis of its likely superiority over the others, given the initial information about both. As a consequence, any joint strategy may become "winning" once it is chosen, since until it is discarded the information collected is only used to update the estimate of its payoffs.

\section*{Appendix 1}

\section*{Estimating the I-0 Coefficients of a Social Accounting Latrix *)}
1. Alternative estimators of i-o coefficients

\subsection*{1.1 Generalities}

As is well known, the fixed coefficient production model is based on the idea that production possibilities can be described through a finite (and sufficiently seall) number of activities. Any two activities differ from each other either because they produce different commodities or because they require different quantities of inputs to produce a given quantity of the same commodity. For any commodity i measured in physical units \(x\), the input-output coefficient for input \(j\) in activity \(k\) is defined:
\[
(\mathbf{k})_{y_{i j}}(\mathbf{k})
\]
(1) \(f_{i j}=\overline{\mathbf{x}_{i}}(\mathbf{k})\)
i.e. as the amount (also in physical units) of input \(j\) devoted to the production of the \(i\) - th commodity in activity \(k\) divided by the amount produced in the same activity for the same commodity.

From (1), dropping the superscript \(k\), i.e. assuming that commodities produced with different activities are identifiable as different commodities, one can derive the definition of the so called Leontief production function:
(2) \(\quad x_{i}=\min \left[\frac{y_{i j}}{\overline{f_{i j}}} \quad ; j=1,2 \ldots m ; i=1,2 \ldots n\right]\)
*) This appendix is largerly based on Scandizzo (1990a)

Expressions (1) and (2) imply: (i) that all fij's>/0 and, (ii) that \(\frac{y_{i j}}{f_{i j}}=\frac{y_{i p}}{f_{i p}}\) for all \(j\) and \(p\) except for the case where one of the coefficients is zero. In the most general case, the observed values of the f's can be thought as consistent with the following mathematical programaing model:
\[
\text { (3) maximize } Z=W(X)
\]
\[
\begin{aligned}
F_{1} X-(X-\bar{C}) & \leq 0 \\
\text { subject to: } & F_{2} X-Y \leq 0 \\
X & \geq 0
\end{aligned}
\]
where \(X\) is an \(n \times 1\) vector of production level \(C\) an \(n \times 1\) vector of final uses, \(Y\) an \(m x\) vector of primary input levels, \(F_{1}\) and \(F_{2}\) respectively an nxn and an man matrix of i-o coefficients. The above model is formed by an arbitrary non convex function of the vector of commodity levels \(X\), under three sets of constraints requiring respectively: (i) that total output, net of intermediate uses, should be at least as great as required by (given) final uses, (ii) that use of primary inputs should not exceed resource availability and, (iii) that each comodity cannot be produced at negative level.

Two cases of special significance of (3) are the simple linear programming problem:
(4) maximize \(Z=P ' X\)
subject to: \(F_{2} X-P \leq 0\)
\[
x \geq 0
\]
where \(P\) is an \(n x 1\) vector of weights, and the Leontief open model:
(5) \(X=F_{1} X+C\)
which can be considered a solution of (1) for the cases where the set of resource constraints is dominated by the set of consumption constraints. In other vords, if \(C\) is sufficiently small, the resource constraint will not be binding and the maximization model in (1) collapses to the set of linear equations that express the second constraint.

A special case of (5), which can be obtained by simply re-naming the variables, is the social accounting matrix (SAM) model:
(6) \(\left[\begin{array}{l}\mathbf{X} \\ \mathbf{Y} \\ \mathbf{C}\end{array}\right]=\left[\begin{array}{lll}\mathbf{F}_{1} & 0 & \mathbf{I} \\ \mathbf{F}_{2} & 0 & 0 \\ \mathbf{O}^{2} & \mathbf{F}_{3} & 0\end{array}\right]\left[\begin{array}{l}\mathbf{X} \\ \mathbf{Y} \\ \mathbf{C}\end{array}\right]\)
where the matrix in square brackets is the SAM and \(X, Y, C\) are combined in a closed-loop Leontief model. In this case, the problem in (3) becones:
(7) maximize \(\mathrm{Z}_{0}=\mathrm{W}(\mathrm{X})\)
\[
\text { subject to: } \left\lvert\, \begin{aligned}
& F_{1} \mathbf{X}-(\mathbf{X}-\mathbf{C}) \leq 0 \\
& \mathbf{F}_{2} \mathbf{X}-\mathrm{Y} \leq 0 \\
& \mathbf{F}_{3} Y-C \leq 0 ; \mathbf{X}, \mathrm{Y}, \mathrm{C} \geq 0
\end{aligned}\right.
\]

\subsection*{1.2 The Fixed Coefficient Model}

Even though analysis of the stochastic nature of the input-output model has received some attention since the fifties (Briggs, 1957), a full treatment of the estimation of the input-output coefficients has been proposed by Gerking only in 1976, with further contributions by Brown and Giarratani (1979) and Gardini (1985). A recent contribution along similar lines for the estimation of input-output coefficients for linear programming models is due to Ray (1985).

Consider a sample of \(h\) units (years or firms) for which we can assume a choice problem of the type outlined in (7). For the \(r\)-th observation ve can urite the equation:
(8) \(Y_{i j}=f_{i j} x_{i r}+u_{i j r}\)
\[
\begin{aligned}
\mathbf{i} & =1,2 \ldots . n \\
\mathbf{j} & =1,2 \ldots . \mathrm{n} \\
\mathbf{r} & =1,2 \ldots \cdot \mathrm{R}
\end{aligned}
\]
where \(u_{i j r}\) is a random variable with mean zero identically and independently distributed for all r .

Under the assumption that both \(\bar{Y}_{i j r}\) and \(X_{i r}\) are measured with error, and, as a consequence, OLS estimates of fijr are both biased and inconsistent, Gerking examines the properties of three different estimators of (6): (i) the instrumental variable estimate proposed by Vald (1940), (ii) a second instrumental variable estimator proposed by Durbin (1954) and, (iii) the TSLS method applied to the set of simultaneous equations obtained by arranging the \(f_{i j}\) 's column by column and adding two accounting identities.

Brown and Giarratani, on the other hand, take issue with the method used by Gerking on three grounds. First, they are not satisfied with Gerking's use of prior information, particularly for what concerns consistency of the input-output estimates with
both sales and purchases identities and the fact that disturbance terns may vary across sample units in response to variations in size, product mix, capital vintage and accounting practices. Second, they claim, due to the "unique" nature of regional input-output models, stochastic techniques may be impossible to apply. Third, the TSLS method yields estinates that neither satisfy accounting restrictions nor possess small sample moments.

In his more recent contribution, finally, Gardini argues on the one hand that Gerking's symultaneous formulation is based on a misunderstanding on the nature of the accounting identities, which are to be considered prior information restricting the parameter space and cannot be used to create new endogenous variables and new structural relationships.

On the other hand, the same author shows that the system of equations obtained by removing from Gerking's system the accounting identities can be simply estimated. In spite of the interdependence among the different equations which yields a structure of seemingly unrelated regression equation, OLS or other single equation methods can in fact be used because the system is formed by input demand equations with the same independent variable (the \(j\)-th output level).

Following Gardini further suggestions on a general formulation for the input-output estimation problem, which coincide with Ray's main model, a fuller stochastic specification to estimate (8) can be obtained by summing over the \(n\) products in the \(r\)-th firm's production plan:
\[
\bar{Y}_{j r}=\sum_{i=1}^{n} f_{i j} x_{i r}+u_{j r} \quad \begin{array}{ll}
j & =1,2 \ldots m  \tag{9}\\
r & =1,2 \ldots R
\end{array}
\]
where \(\bar{Y}_{j r}=\sum_{i=1}^{n} \bar{Y}_{i j r}\) is the input level for the \(j\)-th input and the \(r\)-th firm and \(u_{j r}\) is assumed to have the usual properties:
\(E\left(u_{j r}\right)=0, \operatorname{var}\left(u_{j r}\right)=\sigma^{2} j, \operatorname{cov}\left(u_{j r}, u_{k s}\right)=0\) for \(r \neq s\).

In vector terms, (9) can be written as:
\[
\text { (10) } Y_{j}=X F_{j}+D_{j} \quad j=1,2 \ldots \text { m }
\]
where \(\bar{Y}_{j}\) is the \(R x 1\) vector of input levels for the \(j\)-th input of the \(\mathbb{R}\) firms, \(X\) is the \(\mathbb{R} \times \mathrm{n}\) matrix of the output levels for the \(n\) products and the \(R\) firms, \(F_{j}\) is the \(n \times 1\) vector of input-output coefficients for the \(j\)-th input and \(\sigma_{j}\) is the \(R \quad X \quad 1\) vector of random disturbances \(\mathbf{u}_{\mathbf{j r}}\) for the R firms.

If each sample unit produces the same set of products, oLS applied to each input separately would appear to be the best way to estimate the i-o coefficients in (10). Even if the random disturbances across equations were contemporaneously correlated, in fact, one could not improve on OLS via the Zellner procedure since the same explanatory variables appear in all equations. Note also that only the total values of inputs used and outputs produced would be needed for each sample unit. In other, words, a complete set of men input output coefficients could be obtained by simply regressing \(\mathbb{R}\) observed values of total inputs on \(\mathbb{R}\) observed values of total outputs.

While the 0LS prescription can be broadly accepted as one of the major estimating alternatives, two problems arise with its use, one related to the model interpretation and one to its application. The first problem concerns the nature of the disturbance term \(\mathbf{u}_{\mathrm{jr}}\). This term expresses an additive disturbance in the equation that describes the components of resource use. For each primary resource, therefore, the i-o coefficients are assumed to be affected by a common random disturbance. The regression estimates of the \(f_{i j}\) 's ,in other
words, are based on the assumption that differences in input use between sample units are due solely to differences in output levels, apart from an additive random term.

This interpretation has three main implications for the i-o coefficient estimates: first, their accuracy depends on how wide is the variation of input use and output levels in the sample; second, their reliability is itself inversely proportional to the variability of input use in the sample as compared to the variability of output levels; third, being estimators for an abstract "average" unit, they express a comon central tendency of the technology for each input.

A second problem with the OLS estimates relates to the specification in (9) - (10). If we are confronted with a cross section sample, a stable technology does not exclude that the sample units (e.g. the firms) differ of each other by some characteristic that is important in deternining production performance, the simplest of such a characteristic being the case where different production units produce different sets of products.

In such cases, it is generally possible to improve on OLS via the Zellner (1962) procedure.

It is also important to take into account the fact that only non negative values of the parameters in \(F\) are a priori expected. As Ray (p. 661) points out, a correct specification of the model does not necessarily imply non negativity of the i-o coefficients, because of the error term. Therefore, negative estimates cannot be dealt with by eliminating the corresponding variable and rerunning the regression as it is usually done.

While one of the options open seems to be constrained least squares (Judge and Takayama, 1966), the sample distribution of these estimates is unknown. Furthermore, these estimate lack most of
the desirable properties of OLS.

An alternative option, which appears more desirable, consists in the use of prior information. This can be achieved both through "classical" and Bayesian methods, by assuming that the distribution of the estimates is characterized by a range, a mean and other parameters established on the basis of experience or prior studies. In the case of agricultural micro input-output coefficients, in particular, agronomic studies can usefully provide prior expectations on the plausible range of the estimates.

\subsection*{1.3 Random coefficient models}

Rather than additive disturbances, input output coefficients are more likely to be affected by multiplicative random errors. As noted by several authors 4, including Hildreth and Houck (1968), Sengupta (1976) and Ray (1985), adopting the assumption of multiplicative disturbance introduces randomess directly into the coefficients. Taking for reference equation (10) , this implies:
(11) \(F_{j}=\bar{F}_{j}+W_{j} \quad j=1,2 \ldots\) m
where \(F_{j}\) is a vector of values of the parameters, and \(\mathbf{V}_{j}\) is a vector of randon variables. Equation (11) can thus be restated as:
(12) \(\bar{Y}_{j}=X \bar{F}_{j}+\left(X \mathbf{V}_{j}+\mathrm{O}_{\mathrm{j}}\right) \quad \mathrm{j}=1.2 \ldots \mathrm{~m}\)

To estimate \(F_{j}\) we can apply Hildreth and Houch method provided that we can assume:
(13) \(\quad \mathbf{E}\left(\mathbf{W}_{\mathrm{j}}\right)=0, \quad \operatorname{Var}\left(\mathbf{W}_{\mathrm{ij}}\right)=\sigma_{\mathbf{i}}^{2} \mathrm{I}\)

Because the structure of the random errors implies a violation of the assumption of homoscedasticity, a generalized least square method can also be used to estimate the average values of the random paraneters in (9) and (10).

A more popular method of estimation in the case of multiplicative disturbances consists in measuring for each sample unit the random coefficient relative to the i-th output and the \(j\)-th input. The sample means of the random variable \(f_{i j r}\) :
\[
\begin{equation*}
f_{i j}=\frac{1}{\mathbb{R}} \sum_{r=1}^{R} f_{i j r} \tag{14}
\end{equation*}
\]
\[
\begin{aligned}
& \mathrm{i}=1,2 \ldots \mathrm{n} \\
& \mathrm{j}=1,2 \ldots \mathrm{~m}
\end{aligned}
\]
over the R units sampled, under hypothesis (11) are the best linear ubiased estimates of \(F_{j}\) in (9) and have all the desirable properties of this type of estimates in addition to non negativity.

Several problems may arise, however, in such a direct method of estimation. First, one must measure the quantities of input used for each output. Second, unless all sample units produce all outputs and use all inputs, sample selectivity may be suspected, with consequent loss of unbiasedness of the estimates. Even in the case of large and specialized surveys, single products observations may vary widely and both unbiasedness and efficiency of estimates may be severely compromised.

As an example of problems related to sample measures of input-output coefficients, it is useful to consider what \(\mathbb{L}\) utcher and Scandizzo (1981, p. 145) have to report from one of the largest surveys ( 8000 sample units) specifically designed to measure input-output coefficients in agriculture in North East Brazil. According to these authors, while the estimates of production coefficients were generally obtained through means computed from the survey data, a number of possible sources of error were uncovered. First, despite the large size of the sample, the number of observations of the production relations for any individual crop was quite small, because crops were frequently interplanted. Second, the frequency of observations varied widely among crops and consortiums, and the coefficients estimated for those with only a small number of observations may have been affected by large biases. Third, although the sample points were scattered over large areas, observations of particular crops were spatially concentrated and thus may have given a distorted impression of their average distribution and also, perhaps, of their average production relations, because local
weather, soil quality, and other ecological factors may significantly affect yields, labor requirements, and so forth. Finally, some of the survey data were of better quality than others, because of differences among the survey teams and the degree of understanding of the informants.

In response to these problems, the same authors resort to informal methods of checking and correcting the reliability of the underlying data. In particular, they report the following three step procedure:
(a) calculation of the distribution statistics of the basic input-output relations,
(b) where the same crop is produced in more than one activity, that is, alone or interplanted vith other crops, or both, tests for significant differences in yields,
(c) comparison of the empirical with estinated theoretical distribution of the parameters for different activities (generally nornal) and rejection of outliers.

Because of the problems that beset intensive surveys and the sheer cost of data collection, therefore, it is not apparent a priori that the best route to follow is the estimate of every single coefficient on the basis of sample averages. While this is obvious in the case where non random coefficients may reasonably be assumed, even in the case of multiplicative disturbances, aggregate 0 LS methods are appealing because they do not require measurement of each input-output relation for each sample unit.

One of the main questions that confronts practitioners of input-output methods, in fact, is whether i-o coefficients can be estimated from aggregate data, or at most from a sample of budgetary data of production units. In many cases, indeed, national statistics already include routine generation of data
sets, containing aggregate input and output data at firm level, through a network of "repeated" samples \({ }^{5}\).

\subsection*{1.4 The estimation of the World SAM}

In order to set out the basics for estimating the SAM for the three groups of countries selected, I consider two different data sets: (i) the statistical data from the World Development report (1991) and, (ii) the estimates of three "representative" SAYs concerning, respectively, Sri Lanka (Pyatt and Round), for the LI countries, Portugal (Norton, Scandizzo and Zimmerman (1986)) for the \(n\) countries, and Italy (Scandizzo,1990)) for the HI ones. These two data sets correspond to (i) basic time series for the econometric estimates and, (ii) to the complementary set of prior information.

The algorithm utilized to estimate the input-output coefficients consisted of a routine solving the following constrained maximization problem:

Subject to: \(\begin{array}{rll}\underset{i, t}{\sum} \hat{f}_{i j} \xi_{i t}=\xi_{j t} & j=1, \ldots n \\ \underset{i, t}{\sum} \hat{\mathbf{f}}_{\mathrm{ij}} \xi_{i t}=\xi_{i t} & i=1, \ldots n\end{array}\)
where \(\xi_{i}\) and \(\xi_{j}\) are respectively the \(i\)-th and the \(j\)-th element of the vector \(\xi_{t}{ }^{\prime}=\left[x_{t}, Y_{t}, Z_{t}\right]\) in (6) and is drawn from the World Bank statistics of the \(t\)-th year.

The solution of the problem in (15) corresponds to a combination of the fixed and the random coefficient model. In fact, while estimates of the individual coefficients are obtained as though the underlying model followed a stochastic equation like (11), the constraints follow a fixed coefficient hypothesis like (8). Moreover, a meaningfull solution of the problem may be obtained even with a single set of observations, provided that
suitable prior estimates of the fij's are available.

\section*{Appendix B}

\section*{© Dynanic Computable General Equilibriun Model for the Analysis of Vorld Interdepences}

Consider a three-region decomposition of the primal Leontief equation:
\[
\left[\begin{array}{l}
d X_{1 t}  \tag{1}\\
d X_{2 t} \\
d X_{3 t}
\end{array}\right]=\left[\begin{array}{ll}
A_{11} & A_{12} \\
A_{21} & A_{22} \\
A_{31} & A_{32}
\end{array}\right]\left[\begin{array}{l}
d X_{1 t} \\
d X_{2 t} \\
d X_{3 t}
\end{array}\right]+\left[\begin{array}{l}
d C_{1 t} \\
d C_{2 t} \\
d C_{3 t}
\end{array}\right]+\left[\begin{array}{l}
d Y_{1 t} \\
d Y_{2 t} \\
d Y_{3 t}
\end{array}\right]
\]
where \(\mathrm{dX}_{\text {it }}\) is a vector of changes of production levels at the time for \(n\) commodities produced in the \(i\)-th country group, \(A_{i j}\) denotes a matrix of input output coefficients ( \(i, j=1,2,3\) ) and \(d C_{i t}\) and \(d Y_{i} \quad(i=1,2,3)\) are respectively a vector of changes of final consumption levels and a vector of changes of investment levels in each of the three regions.

Consumption of the \(h\)-th institution in the \(i\)-th region satisfies the behavioral condition:
(2) \(\quad d C_{\text {hit }}=\Gamma_{\text {hit }} \mathrm{dV}^{*}\) hit \(-\Lambda_{\text {hit }} \mathrm{dP}_{\mathrm{t}} \quad i=1,2,3\)
\[
h=1,2 \ldots H
\]
where \(d C_{\text {hit }}\) is a \(3 n x 1\) vector of consumption changes and \(d V^{*}\) hit is the income change of the \(h\)-th institution in the \(i\)-th region, \(\mathrm{dP}_{\mathrm{t}}\) is a \(3 n x 1\) vector of prices in the three regions and \(\Lambda_{\text {hit }} a 3 n x 3 n\) matrix of demand-price coefficients.

Expressions (1) and (2) are related through the definition:
(3) \(\underset{\text { h=1 }}{\mathbb{H}} \quad \mathrm{dC}_{\text {hit }}=\mathrm{dC} \mathrm{it}_{\text {t }}\) \(\mathbf{i}=1,2,3\)

Factor markets are ruled, on the demand side by the Leontief equation:
\[
\left[\begin{array}{l}
d Z_{1 t}^{d}  \tag{4}\\
d Z_{2 t}^{d} \\
d Z_{3 t}^{d}
\end{array}\right]=\left[\begin{array}{lll}
F_{11} & F_{12} & F_{13} \\
A_{11} & \Lambda_{12} & \Lambda_{13} \\
\Lambda_{31} & A_{32} & \Lambda_{33}
\end{array}\right]\left[\begin{array}{l}
d X_{1 t} \\
d X_{2 t} \\
d X_{3 t}
\end{array}\right]
\]
where \(\mathrm{dZ}_{\mathrm{i}}^{\mathrm{d}} \quad(\mathrm{i}=1,2,3)\) is a vector of changes in demand levels of primary factors and indirect tax (subsidy) equivalents 0 in each country group and \(F_{i j}(i, j=1,2,3)\) is an input-output matrix.

On the supply side, the market aknowledges neoclassical supply functions:
\[
\left[\begin{array}{c}
d_{f 1 t}  \tag{5}\\
d_{f 2 t} \\
d_{f} P_{f 3 t}
\end{array}\right]=\left[\begin{array}{lll}
G_{11} & G_{12} & G_{13} \\
G_{21} & G_{22} & G_{23} \\
G_{31} & G_{32} & G_{33}
\end{array}\right]\left[\begin{array}{c}
d Z_{1 t}^{s} \\
d Z_{2 t}^{s} \\
d Z_{3 t}^{s}
\end{array}\right]
\]
where \(\mathrm{dZ}_{\mathrm{it}}^{\mathrm{S}}(\mathrm{i}=1,2,3)\) is a vector of changes in supply levels of primary factors and indirect tax (subsidy) equivalents in each of changes for the same variables and \(G_{i j}(i, j=1,2,3)\) is a matrix of factor price supply coefficients. Note that the characterization of tax equivalents in terms of levels demanded and supplied gives the possibility of endogenizing their determination as well as of assigning them a price. In this context the "demand" \(Z_{i t}^{d}\) tax (equivalent) represents the demand for financing from the part of Government, while the price \(P_{\text {fit }}\) can be interpreted as a measure of the effective tax (subsidy) collected (paid) in correspondence to the amount levied.

In equilibrium:
(6) \(\mathrm{dZ}_{\mathrm{it}}^{\mathrm{d}}=\mathrm{dZ}{ }_{\mathrm{it}}^{\mathrm{S}}=\mathrm{dZ} \mathrm{it}\)

Income accrues to factors according to the equation:
(7) \(d V_{i t}=Z_{i t} d P_{f i t}+P_{f i t} \cdot d Z_{i t}\)
\[
i=1,2,3
\]
where \(d V_{i t}\) is a vector of factor incomes in the \(i\)-th region and \(Z_{i}\) and \(P_{f i t}(i=1,2,3)\) are the vectors of the levels respectively of factor use and prices at the beginning of period \(t\). Income is also distributed from factors to institutions according to the relationship:
\[
\text { (8) }\left[\begin{array}{c}
d v_{1 \mathrm{t}}^{*} \\
d v_{2 t}^{*} \\
d v_{3 t}^{*}
\end{array}\right]=\left[\begin{array}{lll}
w_{11} & \omega_{12} & \omega_{13} \\
\omega_{21} & \omega_{22} & w_{23} \\
\omega_{31} & \omega_{32} & \omega_{33}
\end{array}\right]\left[\begin{array}{c}
d v_{1 t}^{*} \\
d v_{2 t}^{*} \\
d v_{3 t}^{*}
\end{array}\right]+\left[\begin{array}{lll}
R_{11} & R_{12} & R_{13} \\
R_{21} & R_{22} & R_{23} \\
R_{31} & R_{32} & R_{33}
\end{array}\right]\left[\begin{array}{c}
d v_{1 t}^{*} \\
d v_{2 t}^{*} \\
d v_{3 t}^{*}
\end{array}\right]
\]
where \(d V_{i}^{*}(i, j=1,2,3)\) is a vector of institutional incomes in the \(i\) - th region, \(\omega_{i j}(i, j=1,2,3)\) is an income distribution matrix and \(R_{i j}(i, j=1,2,3)\) a matrix of transfer coefficients.

Supply conditions for output prices are determined on the basis of Leontief technology:
\[
\left[\begin{array}{l}
d P_{1 t}  \tag{9}\\
d P_{2 t} \\
d P_{3 t}
\end{array}\right]=\left[\begin{array}{lll}
A_{11} & A_{12} & A_{13} \\
A_{21} & A_{22} & A_{23} \\
A_{31} & A_{32} & A_{33}
\end{array}\right],\left[\begin{array}{l}
d P_{1 t} \\
d P_{2 t} \\
d P_{3 t}
\end{array}\right]+\left[\begin{array}{lll}
F_{11} & F_{12} & F_{13} \\
F_{21} & F_{22} & F_{23} \\
F_{31} & F_{32} & F_{33}
\end{array}\right],\left[\begin{array}{l}
d P_{f 1 t} \\
d P_{f 2 t} \\
d P_{f 3 t}
\end{array}\right]
\]
where ' denotes the transpose.

In order to explore more in detail some of the features of the model, re-write (1) and (2) with the compact notation:
(10) \(d X_{t}=A d X_{t}+\Gamma d V_{t}^{*}-\Lambda d P_{t}+d Y_{t}\)
where \(\quad d x_{t}=\left[\begin{array}{l}d x_{1 t} \\ d x_{2 t} \\ d x_{3 t}\end{array}\right], \quad d V_{t}^{*}=\left[\begin{array}{l}d V_{1}^{*} \\ d V_{2}^{*} \\ d V_{3}^{*}\end{array}\right] \quad\) and \(\quad d P_{t}=\left[\begin{array}{l}d P_{1 t} \\ d P_{2 t} \\ d P_{3 t}\end{array}\right]\)

Osing (9), we obtain:
(11) \(\quad d X_{t}=A d X_{t}+\Gamma d V_{t}^{*}+\Lambda(I-A)^{-1} F P_{f t}+d Y_{t}\)
where \(d P_{f}=\left[\begin{array}{l}d P_{f 1 t} \\ d P_{f 2 t} \\ d P_{f 3 t}\end{array}\right]\)

Applying (7) and (8) yields:
(12) \(d V_{t}^{*}=R_{v p t} F d X_{t}+R_{v z t} d P_{f t}+R_{v v} d V_{t}^{*}\)
where \(\left|\mathbb{R}_{v z t}^{i j}\right|=\omega_{i j} Z_{j t}\) and \(\left|R_{v p t}^{i j}\right|=\omega_{i j} P_{f j t}\)

We can now distinguish two different phases of the model. In a first phase (the "construction" phase) investment displays only an effect of demand expansion, by increasing the consumption of intermediate and final goods. In this case, by substituting (12) into (11) and solving for \(\mathrm{dX}_{\mathrm{t}}\), we obtain:
(13) \(d X_{t}=\Omega_{t}^{-1} d Y_{t}\)
where \(\Omega_{t}=\left[I-A-\Gamma\left(I-R_{v v}\right)^{-1}\left(R_{v p t}+R_{v z t} G\right) F+\Lambda\left(I-A^{\prime}\right)^{-1} F^{\prime} G F\right]\)
and \(G\) is the matrix of factor price-supply coefficients in (5).

Even though the effect of the investment in the first phase is only to expand effective demand, this seemingly once-and-for all shock has an impact also on the parameters of the system, since the matrices \(\left\{R_{v z t}^{i j}\right\}\) and \(\left\{R_{v p t}^{i j}\right\}\) in (12) change in accordance to the new level of factor employment and prices.

After an appropriate gestation lag, that we can set equal to one without loss of generality, the investment made displays an effect also on productive capacity. The factor equilibrium equation for capital (and possibly for labour if investment in human capital has occurred) can thus be uritten in compact form as follows:
\[
\begin{equation*}
d Z_{t}=G^{-1} \mathrm{dP}_{f t}+H d Y_{t-1}=F d X_{t} \tag{14}
\end{equation*}
\]
where \(H\) is a matrix that quantifies the net impact of the investment made on factor supply.

Solving (14) for \(d P_{f t}\) yelds:
(15) \(\quad d P_{f t}=G F d X_{t}-G H d Y_{t-1}\)

Substituting (15) into (11) and (12) and solving for \(\mathrm{dX}_{\mathrm{t}}\) yelds:
(16) \(d X_{t}=\Omega_{t}^{-1}\left[d Y_{t}+t d Y_{t-1}\right]\)
where \(t_{t}=\left[\Lambda(I-A)^{\prime} F^{\prime}-\Gamma\left(I-\mathbb{R}_{v v}\right)^{-1} \mathbf{R}_{v z t}\right] G H\)

In the second phase (the "production period"), therefore, we face two distinct investment effects: (i) the impact of current investment, via the Leontief and the Keynesian multipliers on effective demand and, (ii) the expansion of factor supply due to the investment previously undertaken that has overcome the
gestation lag. While effect (i) is unambiguously positive, the sign of effect (ii) will depend on the balance between the price and the income effects.

Consider first the case where each group of countries is only interested in the short run effect. The planning problem then consists in picking the pattern of tax and subsidy equivalents that gives rise to the highest payoff for any given level of investment. Each country group, therefore, faces the problem of estimating \(n_{t}\) for every combination of tax and subsidy equivalents (every joint strategy). Furthermore, \(\Omega_{t}\) will be a stochastic matrix, so that the pay-off will be \(a\) random variable with \(a\) correspondent probability distribution.

In particular, the expected payoff of the \(h\)-th institution in the i-th country can be specified as folllows:
\[
\begin{equation*}
E\left[\mathbb{I}_{h i}(s)\right]=\int_{a_{h i}}^{b_{h i}} \mathbb{I}_{h i}(s \mid \epsilon) d F_{s}^{h i}\left(\epsilon \mid J_{t}\right) \tag{17}
\end{equation*}
\]
where \(I_{h i}=\frac{d V_{h i}^{*}}{d Y_{i}}\)
and \(E\left[\square_{h i}(s)\right]\) is the expected payoff at time \(t\) to player \(i\) of joint strategy s; \(\epsilon\) is an exogenous disturbance randomly distributed between \(\quad a_{h i}\) and \(b_{h i}, F_{s}^{\text {hi }}\left(\epsilon \mid \sigma_{t}\right)\) is the conditional distribution function assigned by player \(h\) over se at time \(t\) regarding strategy \(s\), given the observation ( \(s\) ) \(\sigma_{t}\).

Applying Bayes theorem:
\[
\begin{equation*}
F_{s}^{h i}\left(\epsilon \mid U_{t}\right)=\frac{F_{s}^{h i}(\epsilon) \cdot L_{s}^{h i}\left(U_{t} \mid \epsilon\right)}{\int_{a_{h i}}^{b_{h i}} L_{s}^{h i}\left(U_{t} \mid \epsilon\right) d F_{s}^{h i}(\epsilon)} \tag{18}
\end{equation*}
\]
where \(F_{s}^{\mathrm{hi}}(\epsilon)\) is the prior d.f. of about \(s\), and \(L_{s}^{\mathrm{hi}}(\mathrm{Ut} \mid \epsilon)\) is the likelihood assigned by \(h_{i}\) to an observation \(J_{t}\), assuming state \(\epsilon\).

Denoting by \(\mathrm{p}_{\mathrm{hi}}(\mathrm{s})\) the probability assigned by player \(\mathrm{h}_{\mathrm{i}}\) to the choice of strategy \(S\) by the other players, the expected payoff of a single strategy for the player \(h_{i}\) is:
\[
\begin{equation*}
E\left[\mathbb{u}_{\mathrm{hi}}\left(\sigma_{\mathrm{hi}}\right)\right]=\sum_{s=1}^{S}\left(E \mathbb{I}_{\mathrm{hi}}(\mathrm{~s})\right) \mathrm{p}_{\mathrm{hi}}\left(\mathrm{~s} \mid \sigma_{\mathrm{hi}}\right) \tag{19}
\end{equation*}
\]
where \(S\) is the number of joint strategies and \(p_{h i}\left(s \mid \sigma_{h i}\right)\) is estimated again by applying Bayes theorem.

Given an initial specification of \(\quad \mathrm{F}_{\mathrm{s}}^{\mathrm{hi}}\left(\mathrm{x} \mid \mathrm{Z}_{\mathrm{t}}\right)\) and \(\mathrm{P}_{\mathrm{hi}}\left(\mathrm{s} \mid \sigma_{\mathrm{hi}}\right)\), equations (17)-(19) provide a basis to pick one particular institutional arrangement for factor exchange for each institution. Assuming that a decision is reached for each country group on the basis of a suitable rule (e.g. simple majority), this allows us to solve the model under one particular \(F\) matrix. Because of the random disturbance \(\epsilon\), however, the solution can itself be used to learn about the payoff distribution and to update each player's decision.

Played in this fashion, therefore, the model evolves stochastically toward a steady state solution, even though in each period investment is allocated entirely exogenously. Rather than investmen level, in fact, choises are assumed to occurr about the institutional framework that has to prevail. As a
consequence, the demand generated by investment is reallocated at each iteration toward the activities that are privileged by the institutional arrangement (the joint stratey) prevailing at that stage.

What happens if we now introduce the effects of the second investment phase? Clearly the investment pattern chosen in period \(t\) will influence not only the payoffs of the same period, but also that of period \(t+1\). Choices of strategies at time \(t\) will depend, therefore, not only on the payoffs generated at that time by investment allocation, but also on those generated at previous times. These in turn were function of the joint strategy selected at that time and in all the preceeding periods.

The introduction of a Bayesian learning mechanism together with a gestation lag has thus the effect of making the model fully dynamic both in the sense that it contains a mechanism of endogenous accumulation (of information) and in the sense that this accumulation results in a time dependent pattern of resource growth and allocation.


GANMA = MARGINAL PROPENSITIES TO CONSUME

BETA = DIRECT FACTOR SUPPLY-PRICE COEFFICIENTS

TETA = PER CAPITA FOOD SUPPLY ELASTICITIES U.R.T. R. PRICES

UNITS = millions of 1988 U.S. \(\$\)

SOURCE : OUR ESTIMATES

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AN INPUT-OUTPUT APPROACH TO ESTIMATING OCCUPATIONAL AND EDUCATIONAL NEEDS IN SOUTHERN ITALY IN \(2000^{1}\)

\subsection*{1.0 INTRODUCTION}

The objective of this research is to estimate the occupational and educational needs in Southern Italy (the South, or Mezzogiorno) over the 1990's. These estimates are based on a program of public investment in the South and expected private investment in the region between 1990 and 2000. Input-output analysis is used to trace the impact of these investment on output and employment. The connection between employment by industry and employment by occupation is based on the current occupational mix of each industry. The educational requirements for each occupational level are detexmined by existing patterns of education for various occupations.

Why might it be important to try to know the future patterns of occupational and educational need in an economy? One reason would be to avoid bottlenecks which could slow the development process by denying expanding industries properly qualified employees for various occupations. A second reason would be to guide investment, social and private, in different types of education and training so as to avoid waste. For both of these justifications a considerable disaggregation of occupations would be a necessary starting point. In the regional context, the employment needs of industries in the future have major consequences for in- or out-migration. For all economies, a bias towards centrally-planned development investment makes research into employment futures more attractive. The less the intended reliance on market solutions to allocation decisions in education and employment, the more appealing are projections of the consequences of development plans for all segments of the economy.

This type of research seems less popular now than it was 20 years ago. Then, perhaps because of the general popularity of

\footnotetext{
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}
planning approaches to economic development, considerable effort was put into studies which purported to give a realistic portrayal of the educational needs which would be associated with particular development scenarios. Unfortunately, the refinement of such useful analytical techniques as input-output analysis had not progressed very far and many of these earlier studies failed the important tests of credibility and accuracy. However, even a more recent useful survey of manpower forecasting practice (Youdi and Hinchcliffe, 1985) contains very little reference to the type of methodology used in this paper. Apparently, much manpower forecasting has relied on simple projections of employment by industrial sector; such extrapolation of current patterns is unlikely to give reliable projections of future manpower needs except in the most stable of economies. Changes in the industrial composition of output, in labor productivity, in the supply of labor, in the occupational mix in different industries, and in the educational requirements for various occupations all make the simple extrapolation of the present risky. \({ }^{2}\)

Recent theoretical research into the process of economic development has found that factors other than investment are more critical in determining the development path for an economy. Models which emphasize human capital (Lucas 1988) have become dominant, confirming earlier research (Denison 1964 and Kendrick 1977). The implications of this research for the present study are that investment in human capital should reflect as accurate a view of the economy's future as possible to avoid waste and optimize growth.

\subsection*{2.0 ECONOMIC DEVELORMENT IN SOUTHERN ITALY}

In Italy, regional economic dualism has been recognized since the unification of the country in 1860. (Schachter and Engelbourg 1988) Over the last four decades the dualistic character of the Italian economy has been the subject of a large number of studies. The Mezzogiorno's backwardness was identified by Voechting (1951)

\footnotetext{
2 There are, however, more sophisticated techniques for forecasting future occupational needs. A technique using input-output relationships as a basis for employment forecasting is described in LeSage and Magura (1991).
}
as due to lack of entrepreneurship. Schachter (1965) suggested policies to encourage labor-intensive economic activities. Other research has found fault with an emphasis on large-scale, capital intensive projects (Dunford 1988), often with weak linkages to other sectors of the Mezzogiorno economy (Baum, Munro, and Schachter 1990). Even the shift out of agriculture of 2.1 million workers between 1951 and 1978 has failed to transform this sector, and through it the rest of the economy, in the manner experienced in most of Western Europe. (Munro and Schachter 1989)

This failure has led to a sustained national effort over the last 40 years to bring a faster development pace to the South and to narrow disparities between South and North. The effort has been singularly unsuccessful. Indeed, the South continues to lag behind the North in virtually every measure of economic performance. Table 1 presents a sample of the statistics for the 1980-90 decade.

TABLE 1

MEASURES OF ECONOMIC PEREORMANCE IN ITALIAN REGIONS
\begin{tabular}{|c|c|c|c|c|}
\hline \multirow[t]{2}{*}{} & \multicolumn{2}{|c|}{NORTH} & \multicolumn{2}{|c|}{SOUTH} \\
\hline & 1980 & 1990 & 1980 & 1990 \\
\hline Population ('000) & 36,460 & 36,555 & 20,019 & 21,184 \\
\hline Employment (`000) & 14,279 & 14,851 & 6,208 & 6,323 \\
\hline Labor Force ('000) & 15,097 & 15,887 & 6,981 & 8,017 \\
\hline Labor Force/Population Ratio & . 414 & . 435 & .349 & . 378 \\
\hline Unemployment Rate (\%) & 5.4 & 6.5 & 11.1 & \(1 . .7\) \\
\hline GRP Per Capita ('000 1985 Lire) & 15,631 & 19,496 & 9,010 & 11,088 \\
\hline Investment/GRP Ratio & . 226 & . 216 & . 274 & . 237 \\
\hline GRP/Worker ('000 1985 Lire) & 39,004 & 47,232 & 29,055 & 37,085 \\
\hline ```
Investment/Worker ('000 1985
Lire)
``` & 8,808 & 10,195 & 7,952 & 8,815 \\
\hline Consumption Per Capita ('000 1985 Lire) & 9,302 & 11,832 & 6,413 & 8,276 \\
\hline
\end{tabular}

In the South, a higher proportion of the population is dependent (not in the labor force), more of the labor force is unemployed, and per capita and per worker measures of output are at least 20\% lower. This disparity is much greater than the approximately \(10 \%\) disparity in investment levels, reflecting the heavy use of public investment as a development tool.

\subsection*{3.0 THE EORECASTING MODEL}

The investment planned (public) and projected (private) in
the South for the 1990-2000 period will have substantial effects on the region's labor markets and on the level and shape of educational requirements. Our forecasting model is designed to project these effects.

To assess the volume and structure of southern labor market one could simply examine the potential labor demand and supply. Since almost one-fifth of the labor force and about half of the youth (14-29 years of age) are unemployed, we could conclude that there are no shortage problems with the aggregate "raw" labor pool which is available. However, such a crude assessment of labor supply would be useless. We must assess the detailed labor needs of the additional productive capacity which will be created in the decade. Such a forecast should be final demand-oriented and should consider the impact of private and public investment, changes in stocks, and exports. However, this paper only considers the effects of investment.

The project design, which is depicted in Figure \(I\), distinguishes between the short run construction period and the long run operational period. Over the short run, it estimates the requirement of output and employment needed to supply inputs for capital goods demanded. That is, during the construction period, certain levels of output and employment are connected with gross investment outlays. In the long run, productive capacity is affected by additional investment and additional permanent jobs are created in the industries where investment takes place and in those sectors that supply inputs to the affected industries.

\subsection*{3.1 The Short Run Output Forecasting Model}

The short run model to assess the impact of output changes is specified as follows:
\(\Delta X=Y \mu(I-a)^{-1}\)
where:
\(\Delta X=\) additional output;
\(Y=a\) demand vector by type or destination of expenditures;
\(\mu=a\) converting destination-origin matrix; and
\((I-a)^{-1}=\) Leontief's inverse.
For the short run the demand vector, \(Y\), is composed of
ordinary investment, \(I\), and public extraordinary investment, \(G\), in

Fig. I Project Design


\section*{Figure 1}

List of Variables
\(\Delta=\) change
\(I=\) ordinary investments
G m public extraordinary investments
\(\mu=\) bridge matrix from destination to origin
A marginal capitol-output ratio
\(y=\) final demand
\((I-a)^{-1}=\) Leontievian inverse
\(X=\) output
\(\mathrm{L}=\) employment
\(\ell=\) forecasted labor productivity
\(\mathrm{P}=\) employment by occupation matrix
\(E=\) occupation by education level matrix

\section*{Superscripts}

Sa south
* \(=\) adjusted values

Subscripts
\(D=\) destination
\(0=\) origin
\(G \equiv\) public extraordinary investments
\(\mathrm{I}=\) ordinary investments
the South. Thus, Equation (1) can be read as:
\[
\begin{align*}
& \Delta X_{p}=\sum_{t=1986}^{2000} \Delta I_{d t} \mu^{S}(I-a)^{-1}  \tag{2a}\\
& \Delta X_{q}=G_{d} S^{S} S^{(I-a)^{-1}} \tag{2b}
\end{align*}
\]
where the subscripts and superscripts are:
\(p=\) ordinary investment;
\(q=\) public extraordinary investment;
\(\mathrm{d}=\) investment by sector of destination;
\(s=\) South; and
\(t=\) time (year).
Note that here only additional investment, \(\Delta I\) (base year to
year 2000), is considered; public investment, \(G\), represent
disbursements from 1986 to 2000 based on a 1986 statute regulating extraordinary public outlays. Investment is reported and/or forecasted by sector of destination, that is, according to the sector which will utilize this investment. Since the model is demand-oriented, investment by sector of destination is transformed into investment by sector of origin with the help of a bridge matrix for the Southern Italian economy, \(\mu \mathrm{S}\). The inverse \((I-a)^{-1}\) is a result of a TRIO (two-region input-output) which aggregates the MRIO (multiregional input-output) of 20 regions into North and South. 3 The latest MRIO was constructed with 44 sectors for the year 1985 (Schachter, 1991) and is based on the 92-sector 1985 national input-output table (ISTAT, 1990). The TRIO is specified in equations (3a) through (11b) and is depicted in Figure II.
\[
\begin{align*}
& x_{i}^{N}=\sum_{j} x_{i j} N N+\sum_{j} T_{i j} N S+Y^{N}  \tag{3a}\\
& x_{i} S_{i}=\sum_{j} x_{i j} S S+\sum_{j} T_{i j} S N+Y^{S} \tag{3b}
\end{align*}
\]

\footnotetext{
\({ }^{3}\) The Northern regions comprise: Val d'Aosta, Piemonte, Lombardia, Liguria, Alto Adige, Veneto, Friuli-Venezia Giulia, Toscana, Emilia-Romagna, Umbria, Marche, and Lazio. The Southern regions comprise: Abruzzi, Molise, Campania, Apulia, Basilicata, Calabria, Sicilia, and Sardegna.
}

Figure II
TRIO, Italy 1985

where:
\(X_{i}{ }^{N}=\) northern sector \(i\) output;
\(x_{i} S=\) southern sector \(i\) output;
\(X_{i j}{ }^{N N}=\) northern sector \(i\) sales to northern sector \(j\);
\(X_{i j} S S=\) southern sector \(i\) sales to southern sector \(j\);
\(T_{i j}{ }^{N S}=\) northern sector \(i\) sales to southern sector \(j\); and
\(T_{i j} \mathrm{SN}=\) southern sector \(i\) sales to northern sector \(j\).
We must deal with four inter-connected sub-matrices, for
internal flows ( X ) and with two for interregional flows ( T ). The direct requirements are specified for internal flows in terms of the technical coefficients, \(a_{i j}\) :
\(\mathrm{a}_{\mathrm{ij}}=\mathrm{X}_{\mathrm{ij}} \mathrm{X}_{\mathrm{j}}\)

The interregional flows are specified in terms of interregional coefficients, \(\mathrm{t}_{\mathrm{ij}}\) :
\[
\begin{equation*}
t_{i j} N S=\frac{T_{i j} N S}{x_{j} S} \quad \text { and } t_{i j} S N=\frac{T_{i j} S N}{x^{N}{ }_{j}} \tag{5}
\end{equation*}
\]

The payments to factors, \(V_{j}\), are specified as a share of total sectoral resources, \(\mathrm{v}_{\mathrm{j}}\) :
\[
v_{j}=\frac{v_{j}}{x_{j}}
\]

The imports, \(M_{j}\), are specified as a share of total sectoral resources, \(\mathrm{m}_{\mathrm{j}}\) :
\[
\begin{equation*}
m_{j}=\frac{m_{j}}{x_{j}} \tag{7}
\end{equation*}
\]
and:
\(\sum_{i} a_{i j}+\sum_{i} t_{i j}+v_{j}+m_{j}=1\)
conversely,
\(\Sigma a_{i j}{ }^{N N}+\Sigma t_{i j} N S+y^{N}=1\)
\(\sum a_{i j} S S+\sum t_{i j} S N+y^{S}=1\)
where \(y\) is the share of final demand, \(Y\), of total resources used:
\(C+I+G+\Delta S+E=Y\)
where:

C = household consumption;
I = ordinary investment;
G = public extraordinary investment;
\(\Delta S=\) change in stocks; and
\(\mathrm{E}=\) exports.
Our first objective is to estimate the impact on sectoral output in the South ( \(X^{S}\) ) and in the North \(\left(X^{N}\right)\) of a change in demand in the South \(\left(Y^{S}\right)\). Therefore, we solve for:
\(x^{N}=\left(I-A^{N N}\right)^{-1}\left(T^{N S} X^{S}\right)\)
\(X^{S}=\left(I-A^{S S}\right)^{-1}\left(T^{S N} X^{N}+Y^{S}\right)\)

For the short run, southern sectoral investment, \(I S\) and \(G S\), creates a demand for capital goods, \(I D\), to be supplied by various sectors. Thus, for the short run the final demand, \(Y\), reflects the derived demand associated with ordinary investment and public extraordinary investment.

\subsection*{3.2 The Long Run Output Eorecasting Model}

Over the long run, there is a close relationship between sectoral investment outlays and changes in output or capacity. If we assume that change in output (economic growth), \(g\), is a function of the amount of capital (ex post equal to savings, s) and its productivity or the marginal output capital ratio \(B\), then:
\[
\begin{equation*}
g=\frac{s}{B} \tag{12}
\end{equation*}
\]

Therefore, we hypothesize that:
\(\Delta Z_{I} S=\sum_{t=1}^{n} I_{D} S_{t B} S\)

The accumulated investment over the period will affect the sectoral capacity requirement according to the sectoral capital productivity ratio, \(B\). The resulting additional sectoral output requirement is in essence an additional "demand" on the economy and is so treated. Therefore, \(\Delta Z^{S}\) becomes part of \(\Delta Y^{S}\) and, using the ( \(I-a)^{-1}\) inverse, we estimate the ensuing sectoral impact.
\(\Delta X_{I}=\Delta Y_{I} S(I-a)^{-1}\)
or, from (13):
\(\Delta X_{I}=\sum_{t=1}^{n} I_{D} S(I-a)^{-1}\)
For extraordinary public investment, we use the combined planned outlays for the period, \(G_{t}\), in the same way as ordinary investment to determine the additional "demand":
\(\Delta Z_{G} S=\sum_{t=1}^{n} G_{t} B^{S}\)
and the total output impact, \(\Delta \mathrm{X}_{\mathrm{G}}\)
\[
\begin{equation*}
\Delta X_{G}=\sum_{t=1}^{n} G_{t} \beta^{S}(I-a)^{-1} \tag{16}
\end{equation*}
\]

\subsection*{3.3 Employment, Occupation, and Education Forecast Model} Once the forecasted sectoral output is estimated, additional labor input requirements are forecasted as a linear relationship with output. However, additional labor input requirements may be satisfied either by an increase in employment or by an increase in labor productivity. So, to assess the net employment requirement we must forecast a cumulative productivity adjustment (1-1) for each sector in each region over the period between 1985 and 2000 where 1 is the forecasted accumulated productivity change.
\(\Delta L_{i}=K_{i} \Delta X_{i}\left(l-l_{i}\right)\)
where:
\(\Delta L_{i}=\) change in additional sectoral labor input requirement; and
- \(K_{i}=L_{i} / X_{i}=\) sectoral labor/output ratio in 1985 , specified for
the South as \(K_{i} S\) and for the North as \(K_{i} N\).
To pass from sectoral employment requirements to occupational requirements we use an employment-occupation matrix, \(p S\) for the South and \(P^{N}\) for the North:
\(\bar{\Delta} \mathrm{P}_{\mathrm{t}} \mathrm{S}=\bar{\Delta}_{\mathrm{L}} \mathrm{S}_{\mathrm{t}} \mathrm{PS}\)
\(\bar{\Delta} \mathrm{P}_{\mathrm{t}}{ }^{\mathrm{N}}=\bar{\Delta} \mathrm{I}_{\mathrm{t}}{ }_{\mathrm{t}} \mathrm{P}^{\mathrm{N}}\)
where \(P^{S}\) and \(P^{N}\) are forecasted occupations for \(t=2000\).
The last passage is from occupations to educational
requirements. We would like to have as detailed a link as possible between occupations and their educational requirements. Unfortunately, this is not yet available and the only available statistics have only a 3-level education sector. This occupationeducation matrix is designated \(E^{S}\) for the South and \(E^{N}\) for the North.
\(\bar{\Delta} \mathrm{E}_{\mathrm{t}} \mathrm{S}=\bar{\Delta} \mathrm{P}_{\mathrm{t}} \mathrm{S} \mathrm{E}^{\mathrm{S}}\)
\(\bar{\Delta} E_{t}{ }^{N}=\bar{\Delta} P_{t}{ }^{N} E^{N}\)

\subsection*{3.4 Model Summary}

We can summarize our model for the short run by utilizing Equations (11a), (11b), (18), (19), and (20).
\(\bar{\Delta} E_{t} N=\left[\left(1-A^{N N}\right)-1\left(T^{N S} X_{X}\right)\right]\left[\begin{array}{ll} \\ (1-1)\end{array}\right]{ }^{N}{ }^{N} E_{E}^{N}\)
\(\bar{\Delta} E_{t} S=\left[\left(1-A^{S S}\right)^{-1}\left(T^{S N} X_{X N}{ }_{+Y} S\right)\right][K(1-1)] S{ }_{P} S E_{E} S\)
where \(Y\) S is obtained for ordinary investment as specified in Equation (2a) as:
\(Y_{p} S=\Delta I S_{d t} \mu^{S}\)
and for extraordinary public investment as specified in Equation (2b) :
\(Y_{q} S=G^{S}{ }_{d \mu} S\)

For the long run for ordinary investment, equations (21a) and (21b) do not change in form but the values for \(Y S\) are different from those specified in Equation (13a):
\(Y_{p} S=\sum_{t=1}^{n} I^{S} d t^{B} S\)
\(Y_{q} S=\sum_{t=1}^{n} G_{t} \beta^{S}\)

\subsection*{4.0 DATA BASE FOR MODEL IMPLEMENTATIONS}

The data base for this paper includes the 1985 MRIO
(Schachter, 1991), the modified national income accounts 1980-1987 (ISTAT, 1990), the DRI (1990) and OECD (1990) economic forecasts, the Banca D'Italia (1988, 1989, and 1990) statistics, the Department of Mezzogiorno Committee for the Creation of New Firms in the South based on PL 44 (Dipartimento per il Mezzogiorno, 1990), IRI (Institute for Industrial Reconstruction), Olivetti, Fiat, and FORMEZ (Center for Study and Training), partial studies done by others (ISFOL, 1987, 1988, and 1989), BLS (1990a and 1990b), and the latest structural studies in the USA (BLS, 1988), and CLMS, (Sum and Harrington, 1986). For public extraordinary investment the original data have been restructured and elaborated for sectors of origin by Cesaretti and Gagliardi (1989). Matrices of occupation and level of education have been elaborated based on the 1981 census (ISTAT, 1986b).

\subsection*{4.1 Endogenous Variables}

Figure I shows the structure of the model.
4.1.1 The TRIO Leontief Inverse This \(88 \times 88\) matrix (see Figure II) is an aggregation, into North and South, of the 20-region, 44sector multi-regional input-output system for 1985 (Schachter, 1991). The interregional flows have been estimated using location quotient techniques. The destination-origin investment matrices
- ( \(\mu\) ) for the South are based on the national ISTAT (1990)
destination-origin investment matrices.

\subsection*{4.1.2 Employment Vector for 44 sectors (North and South) for 1985 (ISTAT, 1990b) :}
4.1.3 Projected Employment depends on changes in output per worker across the 44 sectors (North and South). The labor productivity forecast has been made as follows. For Italy as a whole, between 1950 and 1989, gross domestic product per employed person increased at an annual rate of 4.3\%; it slowed down in the 1970's to \(2.8 \%\) and in the 1980 's to \(2.1 \%\) (BLS, 1990b). For Italy, official data shows an annual rate of increase of \(1.5 \%\) for gross product per capita for 1982-1987; for the same period for Mezzogiorno, the annual rate of increase was 1.4\% (ISTAT, 1990). In terms of value added per:worker, the average annual growth between 1980 and 1990 for the manufacturing sector was \(3.9 \%\) for the North and 4.5\% for the South (SVIMEZ, 1991). Sectorally, the chemical industry had the highest increase in value added per worker of \(8.7 \%\) for the North and \(7.3 \%\) for the South.

We assume that for the manufacturing sectors (7-26) labor productivity will increase at about the same rate of the 1980 's. For Italy as a whole, we used a study completed by Nomisma (1981). To differentiate between North and South, we approximated the relationship to the value added per worker of the 1980's (SVIMEZ, 1991). For agriculture (sector 1), energy (sectors 2-6), consumption (sector 29), transportation and communication (sectors 31-34), and credit and insurance (sector 35 ) we extrapolated the 1980-1987 trend for each sector for Italy as a whole and then applied this regionally (North and South) from the existing 17sector values. Results are shown in Table 2.

TABLE 2

\section*{LABOR PRODUCTIVITY CHANGES TO 2000}
\begin{tabular}{|c|c|c|}
\hline Number & Sector & \[
\begin{gathered}
\text { Labor } \\
\text { Productivity } \\
\text { Change } \\
1-(1-1)^{n} \\
\hline
\end{gathered}
\] \\
\hline 1 & Agriculture & . 0647 \\
\hline 2 & Fossil Fuels & 8425 \\
\hline 3 & Coke & . 8425 \\
\hline 4 & Petroleum & . 8425 \\
\hline 5 & Electricity, Gas, Water & . 8425 \\
\hline 6 & Nuclear Fuels & . 8425 \\
\hline 7 & Ferrous and Non-Ferrous Minerals & . 5517 \\
\hline 8 & Products from Non-Metallic Minerals & . 6589 \\
\hline 9 & Other Metal Products & . 3637 \\
\hline 10-13 & Mechanical & . 7498 \\
\hline 14-15 & Vehicles & . 3712 \\
\hline 16 & Meat Products & . 7487 \\
\hline 17 & Dairy Products & . 7487 \\
\hline 18 & Other Food Products & . 7487 \\
\hline 19 & Beverages & 7487 \\
\hline 20 & Tobacco & 7487 \\
\hline 21 & Textiles and Clothing & . 6897 \\
\hline 22 & Leather and Leather Products & . 6897 \\
\hline 23 & Wood and Wood Products & 4861 \\
\hline 24 & Paper & 4941 \\
\hline 25 & Rubber & 6867 \\
\hline 26 & Manufactured Products, not classified & . 6867 \\
\hline 27 & Construction & . 9744 \\
\hline 28 & Scrap & 1.0 \\
\hline 29 & Trade & 1.0 \\
\hline 30 & Hotels and Restaurants & 1.0 \\
\hline 31 & Land Transportation & . 7575 \\
\hline 32 & Sea and Air Transportation & . 7575 \\
\hline 33 & Related Transport Activities & . 7575 \\
\hline 34 & Communication & . 7575 \\
\hline 35 & Finance and Insurance & . 9478 \\
\hline 36-40 & Services & 1.0 \\
\hline 41-45 & Government & 1.0 \\
\hline
\end{tabular}

A recent study suggests that labor demand is a function of "product-wage," value-added, and technical progress (Prosperetti and Urga, 1989). But, their 1970-1984 empirical study presents a somewhat different picture. While labor demand is positively correlated with value added, it is negatively correlated with
hours worked, "product-wage" and technical progress. This last variable assumes constant returns to scale and constant quality of labor and capital inputs. They find an annual productivity growth of \(2.5 \%\) between 1970-1985 and \(1.6 \%\) for 1980-1985, values which are similar to other sources.

In our study, the estimated productivity change mirrors the DRI/BLS forecasts (about 50\% growth of productivity between 1985 and 2000) for manufacturing but productivity improvement in other sectors is forecasted to be much smaller. Indeed, for trade and services (sectors 28-30, 36-44) we assumed no growth in productivity.

Formally, the sectoral compensatory productivity cumulative change for the South, \(l^{S_{j}}\), has been calculated as:
\[
{ }_{1} S_{j}=(1-p) \frac{\left[(V / L) S_{j} /\left(V / L_{j}\right) I_{j}\right]_{t+n}}{\left[(V / L) S_{j} /(V / L) I_{j}\right] t}
\]
where:
\(p=\left(1+X^{I} t / L^{I} t\right)^{n}\)
\(V_{j}=\) sectoral value added;
\(L_{j}=\) sectoral employment;
\(X=\) total output;
\(n=\) years since start ( \(1 \leq n<15\) );
\(I=\) Italy;
\(S=\) South; and
\(t=1985\) (initial year).

Thus, employment projections for year \(t\) are determined by:
\(L^{\star *}{ }_{j, t+n}=l_{j, t+n} \cdot L^{*}{ }_{j, t+n}\)
where \(L^{*}{ }_{j}\) represents the unadjusted sectoral employment requirement projection and \(L^{* *}\) the productivity-adjusted sectoral employment requirement.
4.1.4 An occupation employment ( \(44 \times 97\) ) matrix for the North and South was estimated from the 1981 Census (ISTAT, 1986b). 4.1.5 A \(97 \times 3\) occupation-education level matrix for the North and the South matrix was estimated from the 1981 Census (ISTAT, 1986b).
4.1.6 Capital-Output Ratio The capital-output ratio vector, \(B_{i}\), was estimated based on 1980-1987 (ISTAT, 1990) and 1970-1984 (ISTAT, 1986a) value added and investment for the South and 19601985 output and investment for Italy (ISTAT, 1987a) using a twoyear lag. Thus, generally:
\[
B_{i}=\frac{1}{\left(I_{t 1}+I_{t 2}\right) /\left(X_{t 3}-X_{t, 1}\right)}
\]

Table 3 shows the estimated values for \(B_{i} S\). Note that manufacturing has a much higher capital productivity than other sectors.

TABLE 3

\section*{MARGINAL CAPITAL-OUTPUT RATIOS ( \(B_{I}\) ) BY SECTOR}
\begin{tabular}{|c|c|c|c|}
\hline Number & Sector & \(\Delta \mathrm{X} / \mathrm{I}\) & \(\mathrm{I} / \Delta \mathrm{X}\) \\
\hline 1 & Agriculture & . 1115 & 9 \\
\hline 2 & Fossil Fuels & . 0374 & 27 \\
\hline 3 & Coke & . 0823 & 12 \\
\hline 4 & Petroleum & . 0668 & 15 \\
\hline 5 & Electricity, Gas, Water & . 1508 & 9 \\
\hline 6 & Nuclear Fuels & . 0662 & 15 \\
\hline 7 & Ferrous and Non-Ferrous Minerals & . 0658 & 15 \\
\hline 8 & Products from Non-Metallic Minerals & . 1948 & 5 \\
\hline 9 & Other Metal Products & 0159 & 63 \\
\hline 10-13 & Mechanical & 2425 & 4 \\
\hline 14-15 & Vehicles & 1350 & 7 \\
\hline 16 & Meat Products & . 0820 & 12 \\
\hline 17 & Dairy Products & . 0870 & 11 \\
\hline 18 & Other Food Product's & . 0999 & 10 \\
\hline 19 & Beverages & . 1707 & 6 \\
\hline 20 & Tobacco & . 1740 & 6 \\
\hline 21 & Textiles and Clothing & 1211 & 8 \\
\hline 22 & Leather and Leather Products & . 1106 & 9 \\
\hline 23 & Wood and Wood Products & . 1750 & 6 \\
\hline 24 & Paper & . 0770 & 13 \\
\hline 25 & Rubber & 1804 & 6 \\
\hline 26 & Manufactured Products, not classified & . 2519 & 4 \\
\hline 27 & Construction & . 0364 & 27 \\
\hline 28 & Scrap & 1575 & 6 \\
\hline 29 & Trade & . 1749 & 6 \\
\hline 30 & Hotels and Restaurants & . 1244 & 8 \\
\hline 31 & Land Transportation & . 0724 & 14 \\
\hline 32 & Sea and Air Transportation & . 0380 & 26 \\
\hline 33 & Related Transport Activities & . 0393 & 25 \\
\hline 34 & Communication & . 0816 & 12 \\
\hline 35 & Finance and Insurance & . 2008 & 5 \\
\hline 36-40 & Services & . 0321 & 31 \\
\hline 41-45 & Government & . 0717 & 14 \\
\hline
\end{tabular}
4.1.7 Exogenous Variables. The exogenous variables are investment by sector. Investment expenditures for our study consist of:
(a) ordinary additions to fixed capital for replacement
(autonomous) and to insure plant capacity (induced output) and
(b) extraordinary public investment aimed at Southern Italian

Development.
Forecasting ordinary investment is risky because of uncertainties connected with technological change, tastes, and international markets. Replacement investment is autonomous in terms of output and is related to the available stock and capitaloutput ratios needed to maintain the productive system at its status guo level. Induced investment is responsive to expected output, availability of loanable funds, cost of capital funds, and previous investment. In the absence of reliable time series data on regional sectoral investment outlays, we relied on partial information from various sources.

For ordinary investment (private and public) problems arose because of the changes in the accounting system of ISTAT and the base of forecasting of DRI. Regional ISTAT unpublished data for 17 sectors for \(1970-1984\) is available at 1970 constant prices (ISTAT, 1986a) while published data is available for 1980-1987 at 1980 prices (ISTAT, 1990). The DRI projections for 1988-1999 (1990a, 1990b, and 1990c) are at 1970 prices but are based on late 1980's (1982-1987) experiences when the annual rate of investment growth averaged 2.5-3.04. Through 1999, therefore, they forecast the same rate of growth. In reality, between 1980 and 1983 Italy experienced a steady decline in investment and therefore the average rate of growth over the 1980-1989 period was less than one percent.

Sectorally, DRI (1990d) forecasts to 1999 investment for eighteen sectors by sector of origin at 1980 prices. We inflated these data to 1985 prices and normalized them with the 1985 official ISTAT data for 1985. This gave us a vector for Italy's investment by sector of origin for 2000 at 1985 prices.

At the regional level, we used separately the 1970-1984 and 1980-1987 data for the South and for Italy and the destinationorigin matrix, \(\mu^{S}(17 \times 44)\) for each year to obtain investment by origin based on the South/Italy ratio. The 1980-1987 data showed an annual growth rate of \(2.1 \%\) for Italy and \(1.8 \%\) for the South. Therefore, we used the 1970-1984 data with more (15) observations for each sector. This relative South/Italy trend was applied to the Italian vectors 1985-2000 to obtain the 2000 investment vectors by origin for the South. Then, we normalized the total to

DRI data assuming the same rate of growth (1.8\% annually for the South) for 1982-1989.

For the extraordinary outlays \(G^{r}{ }_{i}\) we rely on planned expenditures of the public sector as proposed in three investment plans based on the Law for the Development of South of Italy. 64/86 and for which we have details. Planned expenditures are disbursed partially over the plan period and it may take 5-20 years to complete them. The hypothesis of how much will have been disbursed in 2000 is based on the average trends in expenditure by the Dipartimento per il Mezzogiorno, the institution charged by the government to oversee these disbursements.

\subsection*{5.0 IMPLEMENTATION OF THE MODEL AND RESULTS}

As noted above, we are assessing two different impacts. For the short run, the construction period, most of the effect is on the construction and mechanical sectors which must produce capital goods. This does not affect the productive capacity of each sector. The long run impact is determined by how productive capacity will be affected by additional investment. In the former case, temporary employment is created; in the second case, permanent jobs are created. For ordinary investment in the short run, the change in investment will have an effect while in the long run all (accumulated) investment has an effect.
5.1 The Short Run Output and Empleyment Impact

Total ordinary investment in the South was 50,700 billion Lire in 1985. Using a sectoral trend analysis, investment through 2000 above this initial level will be about 6,300 billion Lire. 4 Various extraordinary public investment will disburse 28,217 billion Lire. In Tables 4 and 5 we show the projected impact of Southern investment on output and employment in the South as well as in the North and for all Italy. Note that these projections use only the additional investment for the period since the current level of investment requires the same amount of capital goods and has no additional impact on output and employment.

\footnotetext{
\({ }^{4}\) Note that one may argue that this projection is too low because, between 1985 and 1990, fixed investments in the South increased by 5,600 billion Lire (SVIMEZ, 1991). On the other hand, between 1980 and 1985, the increase was less than 1,000 billion Lire - and our projections are based on long run trends (1970-1987).
}

TABLE 4
CONSTRUCTION IMPACT OE SOUTHERN INVESTMENTS 1985-2000, SOUTHERN ITALY
\begin{tabular}{|l|c|c|c|}
\hline & \begin{tabular}{c} 
Investment \\
(Billion Lire)
\end{tabular} & \begin{tabular}{c} 
Output \\
(Billion Lire)
\end{tabular} & \begin{tabular}{c} 
Additional \\
Employment
\end{tabular} \\
\hline De Vito Law & 777 & 1,578 & 18,461 \\
\hline Subsidies & 10,222 & 21,188 & 229,893 \\
\hline IRI & 1,304 & 2,486 & 35,382 \\
\hline BULL & 203 & 381 & 5,553 \\
\hline OLIVETTI & 583 & 1,222 & 13,369 \\
\hline TEXAS & 1,426 & 2,909 & 35,683 \\
\hline FIAT & 2,631 & 5,345 & 57,979 \\
\hline III PLAN & 2,545 & 5,311 & 55,131 \\
\hline II PLAN & 4,788 & 9,898 & 105,004 \\
\hline \multicolumn{1}{|c|}{ I RLAN } & 3,738 & 7,578 & 85,388 \\
\hline \begin{tabular}{l} 
Total Extra- \\
ordinary
\end{tabular} & 28,217 & \(\therefore 7,896\) & 642,173 \\
\hline Ordinary & 6,331 & \(\ddots\) & 16,161 \\
\hline \begin{tabular}{l} 
Total to \\
2000
\end{tabular} & 34,548 & 74,057 & 171,844 \\
\hline
\end{tabular}

Table 4 shows that ordinary investment would cause a total output expansion of 16,161 billion Lire and public investment 57,896 billion Lire requiring respectively a net increase of 171,844 and 642,173 jobs. Thus, every additional job requires investment of respectively 27 million Lire in the case of ordinary investment and 23 million Lire in the case of public investment. However, the average investment per worker was 8 million Lire in 1980 and 9 million Lire in 1990.

TABLE 5
CONSTRUCTION IMPACT OF SOUTHERN INVESTMENTS 1985-2000, NORTHERN ITALY AND ALL ITALY
\begin{tabular}{|l|c|c|c|c|}
\hline & \multicolumn{2}{|c|}{ NORTH } & \multicolumn{2}{c|}{ ITALY } \\
\hline & \begin{tabular}{c} 
Output \\
(Billion \\
Lire)
\end{tabular} & \begin{tabular}{c} 
Additional \\
Employment
\end{tabular} & \begin{tabular}{c} 
Output \\
(Billion \\
Lire)
\end{tabular} & \begin{tabular}{c} 
Additional \\
Employment
\end{tabular} \\
\hline De Vito & 276 & 2,119 & 1,803 & 20,580 \\
\hline Subsidies & 4,183 & 32,272 & 25,371 & 262,165 \\
\hline IRI & 421 & 3,247 & 2,907 & 38,629 \\
\hline BULL & 57 & 435 & 437 & 5,988 \\
\hline OLIVETTI & 234 & 1,814 & 1,455 & 15,513 \\
\hline TEXAS & 607 & 4,695 & 3,516 & 40,378 \\
\hline FIAT & 1,165 & 9,041 & 6,510 & 67,020 \\
\hline III PLAN & 1,060 & 8,122 & 6,372 & 63,253 \\
\hline II PLAN & 1,947 & 14,891 & 11,845 & 119,895 \\
\hline I PLAN & 1,406 & 10,738 & 8,948 & 96,126 \\
\hline \begin{tabular}{l} 
Total Extra- \\
ordinary
\end{tabular} & 11,356 & 87,375 & 69,164 & 729,548 \\
\hline Ordinary & 3,044 & 22,846 & 19,205 & 194,690 \\
\hline Total to & 14,400 & 110,220 & 88,369 & 924,237 \\
\hline 2000 & & & & \\
\hline
\end{tabular}

As shown in Table 5, the spread effect to the North for all types of investment is projected to be 14,400 billion Lire and 110,000 thousand jobs or about \(20 \%\) in output and \(12 \%\) in employment. This result is due to the expected higher labor productivity growth in the North and because of the large impact on the North-based construction industry.

In the South the sectors most affected are mechanical industries, construction, petroleum, and electric industries. In the North the metallurgical, mechanical, and credit/insurance sectors are the most impacted.

\subsection*{5.2 The Long Run Output and Employment Impact \\ The long term impact reflects the needed additional}
productive capacity to satisfy additional expenditures. We assume that there is a large unused labor force that can be employed through additional capital expenditures and from imports by the . rest of the country. Tables 6 and 7 show the long run effects of investment on the South and on the North and all Italy.

\section*{LONG RUN IMPACT OF INVESTMENT IN THE SOUTH}
\begin{tabular}{|l|c|c|c|}
\hline & \begin{tabular}{c} 
Initial Output \\
Increase ( \(\Delta \mathrm{Y}\) )
\end{tabular} & \begin{tabular}{c} 
Einal Output \\
Increase ( \(\Delta \mathrm{X}\) ) \\
(Billion Lire)
\end{tabular} & \begin{tabular}{c} 
Employment \\
Increase ( \(\Delta \mathrm{L}\) )
\end{tabular} \\
\hline (Billion Lire) & 91 & 199 & 1,985 \\
\hline Devito Law & \(-1,701\) & 3,809 & 36,456 \\
\hline Subsidies & 196 & 451 & 3,390 \\
\hline IRI & 168 & 338 & 4,028 \\
\hline III Plan & 263 & 533 & 6,177 \\
\hline II Plan & 135 & 270 & 3,420 \\
\hline I Plan & 2,254 & 5,600 & 55,276 \\
\hline \begin{tabular}{l} 
Total Extra- \\
ordinary
\end{tabular} & 39,458 & 81,434 & 859,065 \\
\hline Ordinary & 42,012 & 87,034 & 914,431 \\
\hline \begin{tabular}{l} 
Total to \\
2000
\end{tabular} & & \\
\hline
\end{tabular}

TABLE 7
LONG RUN IMPACT OF INVESTMENT IN THE NORTH AND ALL ITALY
\begin{tabular}{|c|c|c|c|c|}
\hline & \multicolumn{2}{|l|}{NORTH} & \multicolumn{2}{|l|}{ITALY} \\
\hline & \begin{tabular}{l}
Final Output \\
Increase ( \(\Delta \mathrm{X}\) ) \\
(Billion Lire)
\end{tabular} & Employment Increase ( \(\Delta \mathrm{L}\) ) & \begin{tabular}{l}
Final Output \\
Increase ( \(\Delta \mathrm{X}\) ) \\
(Billion Lire)
\end{tabular} & Employment Increase ( \(\Delta \mathrm{L}\) ) \\
\hline Devito Law & 30 & 226 & 228 & 2,210 \\
\hline Subsidies & 665 & 5,048 & 4,474 & 41,504 \\
\hline IRI & 75 & 571 & 526 & 3,961 \\
\hline III Plan & 54 & 411 & 392 & 4,439 \\
\hline II Plan & 84 & 637 & 617 & 6,814 \\
\hline I Plan & 42 & 317 & 312 & 3,557 \\
\hline Total Extraordinary & 950 & 7,210 & 6,549 & 62,486 \\
\hline Ordinary & 7,827 & 60,298 & 89,261 & 919,363 \\
\hline \[
\begin{aligned}
& \text { Total to } \\
& 2000
\end{aligned}
\] & 8,777 & 67,508 & 95,810 & 981,849 \\
\hline
\end{tabular}

As expected, over the long run ordinary investment has a greater effect than extraordinary public investment.

Table 8 summarizes the impacts on the South over the study period for both the short and long run.

TABLE 8
SUMMARY OF INVESTMENT IMPACTS IN THE SOUTH
Short Run
\begin{tabular}{|l|c|c|c||}
\hline \begin{tabular}{l} 
Source of \\
Investment \\
Expenditure
\end{tabular} & \begin{tabular}{c} 
Investment \\
Amount \\
(Billion Lire)
\end{tabular} & \begin{tabular}{c} 
Change in \\
Output ( Bil ) \\
Bilion Lire)
\end{tabular} & \begin{tabular}{c} 
Additional \\
Employment ( \(\Delta \mathrm{L})\)
\end{tabular} \\
\hline \begin{tabular}{l} 
Total Ordinary \\
Investment under \\
L.64 (1)
\end{tabular} & 6,331 & 16,161 & 171,844 \\
\hline \begin{tabular}{l} 
Extraordinary \\
Investment (2)
\end{tabular} & 626 & 1,570 & 18,075 \\
\hline \begin{tabular}{l} 
Extraordinary \\
Investment under \\
L.64 (3)
\end{tabular} & 28,217 & 57,896 & 642,173 \\
\hline \begin{tabular}{l} 
Total Extra- \\
ordinary \\
Investment (2+3)
\end{tabular} & 28,843 & 59,466 & 660,248 \\
\hline \begin{tabular}{l} 
Total \\
Investment under \\
L.64 (1+3)
\end{tabular} & 34,548 & 74,057 & 814,017 \\
\hline
\end{tabular}

Long Run 120001
\begin{tabular}{|l|c|c|c|c|}
\hline \begin{tabular}{l} 
Source of \\
Investment \\
Expenditure
\end{tabular} & \begin{tabular}{c} 
Total \\
Investment \\
Expenditure \\
(Bill.Lire)
\end{tabular} & \begin{tabular}{c} 
Initial \\
Output \\
Increase \\
( \(\Delta \mathrm{Y})\) \\
(Bill.Lire)
\end{tabular} & \begin{tabular}{c} 
Final \\
Output \\
Increase \\
( \(\Delta \mathrm{B})\)
\end{tabular} & \begin{tabular}{c} 
Additional \\
Employment \\
\((\Delta \mathrm{L})\)
\end{tabular} \\
\hline \begin{tabular}{l} 
Total Ordinary \\
Investment under \\
L.64 (1)
\end{tabular} & 538,721 & 39,458 & 81,434 & 859,065 \\
\hline \begin{tabular}{l} 
Extraordinary \\
Investment (2)
\end{tabular} & 50,570 & 6,359 & 13,094 & 137,229 \\
\hline \begin{tabular}{l} 
Extraordinary \\
Investment under \\
L.64 (3)
\end{tabular} & 23,771 & 2,554 & 5,600 & 55,276 \\
\hline \begin{tabular}{l} 
Total Extra- \\
Ordinary \\
Investment (2+3)
\end{tabular} & 74,341 & 8,913 & 18,694 & 192,605 \\
\hline \begin{tabular}{l} 
Total \\
Investment under \\
L.64 (1+3)
\end{tabular} & 562,492 & 42,012 & 87,034 & 914,341 \\
\hline
\end{tabular}

The value of accumulated ordinary investment over the 19862000 period is forecasted at 538,721 billion Lire. This is over twenty times the expected disbursement by the public sector for
extraordinary expenditures. The induced effects shown in Table 8 vary due to the sectoral distribution. Sixty percent of ordinary investment is in construction, services, transportation, and public administration where the marginal capital-output ratio is between 12:1 and 31:1; that is, in services it requires 31 Lire of investment for an extra Lire of output and in public administration, 14 Lire.

Extraordinary public investment through the three Annual Plans will mainly be allocated to construction; i.e., infrastructure for which the induced output appears over periods which may be longer than the period of this study.

Modigliani has claimed that investment in the South is insufficient because saving is too low, (Modigliani, 1990) but there are also problems because of the low productivity of capital. It is possible that much of the investment is autonomous and meant to replace old structures and equipment or is meant to respond to technical progress. This could explain why large public investment outlays in the South have caused capital deepening and labor savings but have not made a significant contribution to lessening hard-core unemployment.

\subsection*{5.3 The Short and Long Run Impact of Investments: Output and Employment}

Our analysis has considered the short run effects the recent legislation for extraordinary investment in the South. Other extraordinary investment have been and will continue to be disbursed through the year 2000. Between 1980 and 1987 these accounted for \(9.6 \%\) of all investment in the South, with annual proportions ranging from \(12.0 \%\) in 1983 to \(7.2 \%\) in 1987 (SVIMEZ, 1990). These outlays will also have an impact on output and employment. Table 8 indicates that for the short run \(9.6 \%\) of additional investment by the year 2000 would increase output by 626 billion Lire creating an increase in short run employment of 18,075. In the long run, the employment effect would be much more substantial - 187,329 additional workers.

As one might expect, in the short run public investment has a larger effect than additional ordinary investment. Table 8 showed that in the short run 814,000 workers would find employment due to
investment of which 660,000 was created by new and old extraordinary investment. For the long run again, the "old" extraordinary outlays are included in the base but the new outlays are additional. Therefore, through the year 2000, an additional 914,000 permanent jobs will be created in the South of which 193,000 will be due to extraordinary old and new outlays.

We now turn to examine the occupational detail of the increased employment levels. The first stage is to review the sectoral employment increases. Table 10 provides projections for the sectors with an increase in employment of more than 20,000 by 2000.

TABLE 10
EMPLOYMENT INCREASE BY SECTOR IN THE SOUTH*
\begin{tabular}{|c|c|c|c|c|c|}
\hline Sector Number & Sector Name & Short Term & Rank & \[
\begin{gathered}
\hline \text { Long } \\
\text { Term } \\
(2000) \\
\hline
\end{gathered}
\] & Rank \\
\hline 1 & Agriculture & -- & --- & 71,167 & 3 \\
\hline 5 & Electricity, Gas, Water & --- & --- & 27,672 & 13 \\
\hline 10 & Metal Products & 61,550 & 4 & --- & \\
\hline 11 & Mechanical Products & 113,463 & 2 & --- & \\
\hline 13 & Electric and Electronic Products & 60,296 & 7 & --- & \\
\hline 14 & Auto Vehicles & 28,052 & 9 & --- & \\
\hline 27 & Construction & 168,520 & 1 & 45,393 & 6 \\
\hline 28 & Scrap & 31,873 & 8 & 38,772 & 10 \\
\hline 29 & Trade & 81,150 & 3 & 143,141 & 1 \\
\hline 31 & Transportation & 22,108 & 10 & 52,551 & 5 \\
\hline 34 & Communication & - & & 29,408 & 12 \\
\hline 35 & Finance and Insurance & - & & 32,778 & 11 \\
\hline 36 & Services & 61,250 & 6 & 90,501 & 2 \\
\hline 38 & Education & 61,372 & 5 & --- & \\
\hline 40 & Cultural and Recreation & --- & & 54,887 & 4 \\
\hline 41 & Government & --- & & 38,907 & 8 \\
\hline 42 & Public Health & --- & & 38,268 & 9 \\
\hline 43 & Domestic Services & --- & & 47,756 & 7 \\
\hline & Total & 689,634 & & 711,201 & \\
\hline
\end{tabular}
* Sectors with an employment increase of more than 20,000.
. Table 10 indicates that in the short run ten sectors will account for \(85 \%\) of all additional employment, mostly construction and
mechanical. In the long run, thirteen sectors account for \(78 \%\) of additional employment but now mainly in trade and services. No manufacturing sector will have an employment increase of over 20,000. This repeats the pattern of the \(1980^{\prime \prime} \mathrm{s}\).

\subsection*{6.0 INVESTMENT IMPACT ON OCCUPATIONS AND EDUCATIONAL REOUIREMENTS}
6.1 Impacts on Occupational Needs

The effect of increased employment resulting from investment on occupations is shown in Table 11.

TABLE 11
EMPLOYMENT INCREASE BY OCCUPATION IN THE SOUTH*
\begin{tabular}{|c|c|c|c|c|c|}
\hline Occupation Sector Number & Sector Name & Short Run & Rank & \[
\begin{aligned}
& \text { Long } \\
& \text { Run } \\
& (2000) \\
& \hline
\end{aligned}
\] & Rank \\
\hline 1 & Teachers & 48,527 & 4 & 24,309 & 11 \\
\hline 27 & Electricians & 50,913 & 3 & 93,905 & 1 \\
\hline 31 & Office Personnel & 27,379 & 9 & 49,706 & 4 \\
\hline 35 & Managers & --- & & 21,618 & 13 \\
\hline 37 & Farm Workers & --- & & 39,558 & 5 \\
\hline 45 & Metal Workers & 107,527 & 2 & 25,763 & 9 \\
\hline 47 & Mechanics & 35,251 & 6 & 26,003 & 8 \\
\hline 49 & Tool and Dye Makers & 35,122 & 7 & --- & \\
\hline 71 & Construction & 132,470 & 1 & 39,285 & 6 \\
\hline 73 & Electricians & 31, 048 & 8 & 24,303 & 12 \\
\hline 77 & Tradesman & 46,360 & 5 & 81,663 & 2 \\
\hline 78 & Salesman & --- & & 31,014 & 8 \\
\hline 83 & Vehicle Drivers & 25,738 & 10 & 34,705 & 7 \\
\hline 93 & Barbers, Beauticians & --- & & 25,173 & 10 \\
\hline 95 & Guards, etc. & 23,073 & 11 & 72,085 & 3 \\
\hline & Total & 563,408 & & 589,090 & \\
\hline
\end{tabular}
* Occupations with an employment increase of more than 20,000 .

As expected, over the short run the occupations which show the largest employment increase are in construction and metal workers (42\% of the total employment increase). Moreover, 67\% of all employment increase is in eleven out of the total of ninety-seven occupational classifications. We must note that these occupational demand characteristics are due to the fact that the expenditure impact is only for capital goods that are usually
supplied by these sectors. The long run impact on occupational requirements should be quite different than in the short run because investment impacts become distributed across all sectors. Nevertheless, Table 11 shows that, even considering this, thirteen occupations account for \(64 \%\) of all employment increase. This increase is concentrated in service and trade occupations with manufacturing and construction occupations becoming much less important over the long run.

\subsection*{6.2 Impacts on Educational Needs}

As was noted earlier, the occupation/education matrix only has three educational levels. Thus, it only provides a weak insight into the final stage of our study. The educational needs breakdown associated with increased employment in the South in the long term is shown in Table 12.5

TABLE 12
EDUCATIONAL NEEDS IN THE LONG RUN (2000)
\begin{tabular}{|l|l|c|c|}
\hline & University & High School & Other \\
\hline Ordinary Investment & 71,979 & 165,348 & 621,738 \\
\hline Extraordinary Investment & 2,333 & 7,412 & 45,531 \\
\hline Total & 74,311 & 172,760 & 667,269 \\
\hline
\end{tabular}

From this, it would appear that the planned and projected investment program will not impose major needs on the educational resources and institutions of the South. However, a more comprehensive connection between occupations and education levels is needed before this could be a definite conclusion from our research. \({ }^{6}\) Moreover, significant expansion in the educational

\footnotetext{
5 Changes in educational needs associated with construction activity and related short run investment-related needs would not be a good guide to educational investment. In the short run, any investment in human capital would be in the nature of short-term training.
- \({ }^{6}\) A sophisticated methodology to sharpen understanding and measurement of the links between occupational groups and education is presented in de Grip, Groot and Heijke (1991).
}
sector would require consideration of its own effects on output across all sectors.

\subsection*{7.0 CONCLUSIONS}

Our results are based on 1985 information and could be modified with data available for 1990. Employment in the South increased by 514,000 (8\%) between 1980 and 1990 and by 182,000 (2.7\%) between 1985 and 1990. Our projections show an employment increase of 732,000 by 2000, an increase of better than \(10 \%\). Even though it is based on a static model, our forecasts reflect only partially the characteristics of the employment structure of the 1980's. Over the past decade, agricultural, manufacturing, and construction industries suffered a reduction of \(28 \%\), \(16 \%\), and 6\%, respectively while employment in services increased by \(40 \%\) and in public administration by 22\%.

TABLE 13
ACTUAL AND FORECASTED EMPLOYMENT IN THE SOUTH (IN THOUSANDS)
\begin{tabular}{|l|r|r|r|r|}
\hline & 1980 & 1985 & 1990 & 2000 \\
\hline Agriculture & 1,479 & 1,239 & 1,091 & 1,310 \\
\hline Energy & 56 & 59 & 63 & 89 \\
\hline Manufacturing & 960 & 829 & 813 & 940 \\
\hline Construction & 683 & 693 & 645 & 718 \\
\hline Services & 2,079 & 2,622 & 2,898 & 3,314 \\
\hline Public Administration & 1,207 & 1,373 & 1,467 & 1,508 \\
\hline Total & 6,463 & 6,796 & 6,977 & 7,709 \\
\hline
\end{tabular}

More than half of the jobs will be created in service sectors, between 1990-2000 but because of the large base there will be only an \(8 \%\) overall increase over the decade. Between 1985 and 2000 a reversal of the trend in manufacturing \((111,000)\) and construction \((45,000)\) with a \(14.15 \%\) growth over the years.

As noted above, the investment program's impact on employment will favor particular occupations and, probably, require redirection of the South's educational expenditures. Definite conclusions on this last matter must await a more complete analysis of relationships between occupations and education.

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Analysis of Hokkaido Economy and its Forecasts to the Year 2000 with the HOKKAIDO MACRO I-O INTEGRATED MODEL

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Analysis of Hokkaido Economy and Forecasts to the Year 2000
with the HOKKAIDO MACRO I-O INTEGRATED MODEL***

By
Osamu Nakamura* and Atsushi Seto**

\section*{I INTRODUCTION}

The purpose of this study is to analyze the economic structure of Hokkaido and to forecast the Hokkaido economy with scenario analysis by using the Hokkaido Macro I-O integrated model.

Hokkaido, which is located in the northeast of Japan, is the second biggest island in Japan, and is rich in natural resources. Hokkaido has only a century of history in terms of regional development and modern civilization after the Meiji Restoration in 1868. From that time to the end of WWII, the Japanese government had been promoting Hokkaido development with a view to ensure national security against Russia and to exploit natural resources through specialization in agriculture, fishery, mining, pulp \& paper, and iron \& steel.

After WWII, those industries have continued to be dominant, and high value added industries have not matured in Hokkaido, even though Japan as a whole has experienced a restructuring of its economy, from heavy industry oriented to high value-added industry oriented.

In 1951 the Hokkaido Development Agency was established to introduce special subsidies into Hokkaido to succeed pre-war government development policies. Since then, national subsidies were given in abundance for the development of infrastructure such as roads, seaports, river-engineering, dams, and agriculture infrastructure.
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Although the amount of government expenditures for public works to regions depends on the population and the land area, expenditure to Hokkaido has remained over \(10 \%\) of total public works by the Japanese government (see TABLE-1). Its overdependency on government support resulted in the current weakness of high value added industries such as the automobile, electronics, and machinery industries.

TABLE-1 JAPAN AND HOKKAIDO IN 1989
\begin{tabular}{|c|c|c|c|c|}
\hline & & (A) JAPAN & (B) HOKRAIDO & (B/A)\% \\
\hline LAND AREA & K=2 & 377,719 & 83,409 & 22.1 \\
\hline POPULATION & thousand & 122,744 & 5,642 & 4.6 \\
\hline REAL-GDE & billion \(\ddagger\) & 384,509.6 & 14,185.4 & 3.7 \\
\hline PER CAPITA INCOME & aillion \(\ddagger\) & 313 & 251 & 80.2 \\
\hline PUBLIC NORES & billion \(¥\) & 7,405.5 & 793.0 & 10.7 \\
\hline
\end{tabular}

Therefore, Hokkaido is heavily dependent on the rest of Japan for manufactured goods. As a result, effective demand stimulated by fiscal policy in Hokkaido leaks out to the rest of Japan, and Hokkaido has a great domestic trade imbalance. At the same time, less opportunity to work accelerates population out-flow to Tokyo and the surrounding area.

However, after the PLAZA-Agreement in September 1985, and due to the low interest rates, low oil prices, the appreciation of the Japanese yen against the US dollar, and Japanese government's fiscal policy, an economic boom, the 'Heisei Boom', began in Japan and continued to January 1991. This was the second longest post-war economic boom in Japan. This boom affected regional economies favorably and the Hokkaido economy was also affected by the boom, although with a time-lag. Furthermore, in spite of Japanese recession, the Hokkaido economy continues its boom (see Figure-1).

Regarding the industrial structure in Hokkaido during the Heisei Boom period, the tertiary industry expanded because of a great number of tourists from the other regions of Japan, and the traditional industries mentioned above, except coal mining and the forestry industry, were revitalized by the demand from the rest of Japan as well.


TABLE-2 SHARE OF SECTORAL OUTPUT IN HOKKAIDO, 1975-1989
\begin{tabular}{lrrrr} 
& 1975 & 1980 & 1985 & 1989 \\
\hline 1 Agricul., Forest., Fish. & 10.7 & 7.6 & 7.0 & 6.2 \\
2 Mining & 1.3 & 1.2 & 0.8 & 0.5 \\
3 Mnufacturing & 13.2 & 13.7 & 11.2 & 12.0 \\
3-1 Light Industries & 3.4 & 3.3 & 2.9 & 3.4 \\
3-2 Industrial Materials & 4.2 & 4.3 & 3.3 & 3.5 \\
3-3 Processing \& Assembling & 4.6 & 6.1 & 5.0 & 5.1 \\
4 Construction & 12.2 & 13.3 & 12.4 & 12.6 \\
5 Private Services & 51.9 & 54.4 & 57.7 & 58.7 \\
6 Public Services & 13.5 & 12.4 & 13.5 & 12.8
\end{tabular}

Therefore, we are going to study the Hokkaido economy and to make forecasts regarding the Hokkaido economy up to the year 2000 by using the HOKKAIDO MACRO I-O INTEGRATED MODEL with scenario analysis, in terms of not only macro economy, but also sectoral economy.

The paper is organized as follows. Section 2 discusses the method of study. Section 3 explains the econometric model of Hokkaido. Section 4 refers
to the results of scenario analysis using the model. Finally, section 5 summarizes the study with concluding remarks.

\section*{II MODEL SYSTEM}

In this study, we intend to analyze the Hokkaido economic structure and to forecast future trends in the Hokkaido economy by using the HOKKAIDO MACRO I-O INTEGRATED MODEL. First, we will explain the total model system which comprises three models: a macro econometric model of Hokkaido, a macro econometric model of the rest of Japan, and an I-0 model ( 45 sectors) of Hokkaido. Next, the macro-model linkage between Hokkaido and the rest of Japan, and the linkage between the macro-econometric model of Hokkaido and the I-0 model of Hokkaido.

This project was originally started to forecast the performance of the Hokkaido economy with a macro econometric model (Nakamura and Seto, 1989). However, it is difficult to forecast the performance of a regional economy only using an independent regional macro model, as there are many variables which cannot be endogenized in the model. Therefore, we divided the Japanese economy into two economic parts, the Hokkaido economy and the rest of Japan's economy. Taking this approach, exogenous variables in Hokkaido macro model can be endogenized in the total model system (Seto, 1991).

Both macro econometric models, of Hokkaido and the rest of Japan, have similar model specifications for the linkages and comparisons of the model. The macro model of Hokkaido consists of 7 sub-blocks, including 95 equations, and the macro model of the rest of Japan consists of 9 sub-blocks, including 128 equations.

Generally, we can say that a regional economy is dependent on the national economy, and the economic activity on sectoral basis depends on final demand as explained by I-0 techniques. Therefore, we did make three models as a total system in order to look into the Hokkaido economy in terms of not only macro economy, but also of sectoral economy (Nakamura and Seto, 1990).

Figure 2 indicates the relationship of three models. In the total model system, each macro model is computed simultaneously, and both these models are linked recursively, affecting mutual interdependence on each other (as for the model specification, we will explain in Section 3 in detail), and each

GDE component of the Hokkaido macro model links each final demand which corresponds with the fixed share in the Hokkaido I-O model.

FIGURE-2 TOTAL MODEL SYSTEM


In this study, even if there are some problems, we make use of basic I-O techniques in order to calculate the economic activities on the sectoral basis by linking the GDE components, which are endogenized in the macro model, with the final demand of the I-0 model as follows.

Equation (1) is the familiar I-O relationship. If inverse matrix \((\mathrm{I}-\mathrm{A})^{-1}\) is computed*, one can study the direct and indirect effects of changes in final demand (F) on sectoral gross output (X).
\[
\begin{equation*}
X=(I-A)^{-1} * F \tag{1}
\end{equation*}
\]
* In the Hokkaido I-0 Model, the inverse is used as follows:
\[
X=[I-(I-M-N) A]^{-1}\left[(I-M-N) F_{(D)}+E\right]
\]

If we integrate the final demand (F) with the GDE components (G), calculated in the macro model considering the fixed share ( H ), which is a socalled CONVERTER, sectoral gross output can be calculated in the model according to the changes in (F) (see equation (2) ).
\[
\begin{equation*}
F=H * G \quad(H: g i j / G) \tag{2}
\end{equation*}
\]
where, (gij) is an element of final demand.

\section*{III MACRO ECONOMETRIC MODEL OF HOKKAIDO}

Here, we will explain the macro econometric model of Hokkaido.
The Hokkaido macro model consists of the following 7 sub-blocks: (1)Real Expenditure, (2)Nominal Expenditure, (3)Prices and Wage rate, (4)Production, (5)Distribution (Income), (6)Public Finances, and (7)Population and Labour.

The macro model is basically dependent on the demand-oriented type model. GDE is calculated in identity by summing up GDE components such as private final consumption expenditure, government consumption expenditure, housing investment, private non-housing investment, government investment, increase in stock, exports, and imports. On the other hand, the model has a production function (Cobb=Douglas Type) from which GDP capacity can be derived. This GDP capacity affects the real expenditure block by way of price mechanisms, which are explained by labour productivity variable. In this sense, this model can be said to be a "Supply-Demand-oriented type model".

Next, we will look into the main equations by block (for details, see APPENDIX A: results of regressions).
(1)Real Expenditure block: this block consists of 13 equations. Real Domestic Expenditures(RGDE) is an aggregate of seven components, as mentioned above. Each real expenditure is determined in the behavioral equation (government consumption and government investment coming from nominal expenditure block, and real government consumption and investment are deflated by each deflator in the identity).

For example, final private consumption expenditure can be presented as follows:
(1976-1989)

\(R R=0.976548 \mathrm{SD}=1550086 \mathrm{DW}=2.605\)

According to the regression result of the consumption function, real private final consumption expenditure \((R C P)\) is dependent on real disposal income(YD/PCP), the money market rate(IRC), and lagged consumption expenditure \((\operatorname{RCP}(-1))\).
(2)Nominal Expenditure block: This block consists of 14 equations. Each nominal expenditure is determined by multiplying real expenditure by implicit deflators which are endogenized in the price sector. However, nominal government consumption is dependent on the government revenue of Hokkaido, and nominal government investment is explained by both public works in Hokkaido and agricultural development expenditure of Hokkaido.
(3)Prices and Wage rate block: The prices and wage rate block consists of 9 equations, such as the wholesale price index(WPI), the consumer price index(CPI), each implicit deflator, and wage rate functions. Prices and implicit deflators, apart from both export and import prices, depend on the corresponding implicit deflators of the rest of Japan, respectively. The export price depends on the output price of the total industry in Hokkaido and the lagged export price. On the other hand, the import price is determined by the wholesale price of the rest of Japan and the lagged import price. Wage rate(W) function is considered as a function of Japan's CPI(JCPI) which is calculated by the CPI of Hokkaido and the CPI of the rest of Japan with GDP weights, real GDE(RGDE), which explains labour demand, and the number of labour(LN), which explains the labour market supply of Hokkaido. This behavioral equation is presented as follows:
(1976-1989)

\[
\mathrm{RR}=0.992082 \quad \mathrm{SD}=0.0156479 \quad \mathrm{DW}=1.8571
\]
(4)Production block: This block consists of 4 equations centering around Cobb=Douglas type production function. Real capital stock(RKPC), real depreciation of capital(RDFC), and labour productivity(RGDEC/LN), are also
determined in this block. Production function(RGDEC) is as follows:
(1976-1989)
\[
\begin{aligned}
& R R=0.945436 \mathrm{SD}=0.0254283 \mathrm{DW}=1.08473
\end{aligned}
\]

According to the regression result of production function, we can see that Hokkaido's economy is dependent on the number of labour(LN) rather than on capital stock(RKPC). Compared with the production function of the rest of Japan (the coefficient of capital stock is around 0.5 and the coefficient of the number of labour is around 0.5), Hokkaido's economy is characterized as a labour intensive economy.*
(5)Distribution(Income) block: This block consists of 23 equations, such as employees wage income, household property income, proprietor's income, and corporate income, etc.. This block plays a very important role in linking the real economy with the nominal economy in the model. There is a feedback loop between the I-O model and the macro model of Hokkaido to link the GDP which is derived from the \(\mathrm{I}-\mathrm{O}\) model of Hokkaido with macro economic variables as one of the explanatory variables in equations of this block.

According to the regression result of corporate income, corporate income(YCP) is dependent on real GDP which is a composite variable consisting of aggregated sectoral value-added(GDP), prime rate(IRP), and wage rate( \(W\) ).
(1976-1989)
\[
\begin{array}{r}
\mathrm{YCP}=\frac{1.20981 \mathrm{E}+06+(\underset{4}{3} 340109 *(\mathrm{GDP})-33791.4 *(\mathrm{IRP})-1.42363 \mathrm{E}+06 *(\mathrm{~W})}{(-1.66)}(-6.11) \\
\mathrm{RR}=0.908218 \mathrm{SD}=65306.5 \mathrm{DW}=2.19484
\end{array}
\]
\[
\begin{aligned}
& * \text { Cobb=Douglas type production function of Japan macro model } \\
& \text { LOG }(\text { RGDPC })=1.93819+0.51615 * \operatorname{LOG}(\mathrm{RKP})+0.48385 * \mathrm{LOG}(\mathrm{LN}) \\
& \mathrm{RR}=0.99787 \mathrm{SD}=0.01 \mathrm{DW}=0.843
\end{aligned}
\]
(6)Public Finance block: This block, which consists of 16 equations, can be divided into three categories, such as Budget for Hokkaido Development from the central government(XGCD), revenue of local government(VGL), and expenditure of local government(XGL). It is worth noting that the Budget for Hokkaido Development(XGCD) is determined by multiplying the share(SXGCD: \(10.3 \%\) in 1980, \(10.7 \%\) in 1989) with total public works by the Japanese government(JXGPW) as follows:
\[
\text { XGCD }=\text { SXGCD*JXGPW }
\]

The budget for Hokkaido Development from the Japanese government(XGCD) is determined by a definition function which consists of the share of Budget for Hokkaido Development from the Japanese government(SXGCD) to total public works by the Japanese government(JXGPW).
(7)Population and Labour block: This block deals with demographic variables, such as population inflow and outflow (social increase-decrease), number of births and deaths (natural increase-decrease) as endogeneous variables. Furthermore, the number of employees, the number of unemployed, and so on are determined in this block. It is noteworthy that the GDP derived from the I-O model appears in unemployment rate function as an explanatory variable and there is a feedback loop between the macro model and the I-O model in this block. For example, two behavioral equations are presented as follows:
(1976-1989)
```

LOG(POPOUT) =-7.38093+0.793285*LOG(RGDE)+0.457032*LOG(LDM/JLDM)
+0.530606*LOG(POPOUT(-1)
RR=0.729795 SD=0.0336016 DW=1.32774

```

According to the regression result of the population outflow function, population outflow (POPOUT) is explained by real GDE, the ratio of effective job opening ratio in Hokkaido (LDM) to effective job opening ratio in Japan(JLDM), and lagged population outflow(POPOUT(-1)).
(1976-1989)

```

    \(+0.22267 *(\operatorname{LUN}(-1))\)
        \(\mathrm{RR}=0.914206 \quad \mathrm{SD}=0.0587471 \quad \mathrm{DW}=2.23837\)
    ```

According to the regression result of the number of unemployment function, the number of unemployed (LUN) is determined by aggregated sectoral value-added(GDP) divided by the implicit deflator for GDE (PGDE), the lagged wage index(WI(-1)), and the lagged number of unemployed(LUN(-1)).

\section*{IV Results of Scenario Analysis}

In the econometric model, each equation is based on economic theory, and we can understand the characteristics of the economy if we take into consideration the model specifications and coefficients of the explanatory variables. However, it is difficult for us to capture the cause and effect relationship, because many equations in the model are determined simultaneously. Therefore, we make scenario analyses and study the impact of some scenarios on the economy comparing standard simulation (Baseline projection) with each alternative scenario using the model system.

In the medical science field, doctors could conduct experiments to determine if the medicine works effectively on mice, instead of testing on human body. However, in the social science field, we could not conduct experiments to determine if the policy is effective on society. Therefore, an econometric model enables us to examine the efficiency of the policy.

In this section, we intend to analyze characteristics of the Hokkaido economy through scenario simulations using the HOKKAIDO MACRO I-O INTEGRATED MODEL.

IV-1 Dynamic Simulation Test (Final Test) and Multiplier Test

Before conducting scenario analyses, we need to know the model reliability by the Final Test in order to compare estimated data with actual data during the sample periods of regression, and the Multiplier Test is conducted to
attain the dynamic characteristics of the model through the multiplier effects.
TABLE- 3 indicates the results of the Final Test. The average deviation between estimated real GDE and actual real GDE is \(0.91 \%\) during the regression period from 1976 to 1989. It can be said that this average deviation is fairly small and the model is reliable for future simulations.
\begin{tabular}{|c|c|c|c|c|}
\hline PERIOD & ESTIMATED & ACUTUAL & RESIDUAL & DEVIATION(\%) \\
\hline 1978 & 1085 & 1079 & -5.509 & -0.51 \\
\hline 1979 & 1173 & 1179 & 5.766 & 0.49 \\
\hline 1980 & 1190 & 1201 & 10.820 & 0.90 \\
\hline 1981 & 1190 & 1194 & 3.893 & 0.33 \\
\hline 1982 & 1202 & 1228 & 25.980 & 2.12 \\
\hline 1983 & 1209 & 1208 & -1.360 & -0.11 \\
\hline 1984 & 1246 & 1239 & -6.585 & -0.53 \\
\hline 1985 & 1240 & 1263 & 23.170 & 1.84 \\
\hline 1986 & 1248 & 1272 & 23.570 & 1.85 \\
\hline 1987 & 1344 & 1356 & 11.450 & 0.84 \\
\hline 1988 & 1401 & 1419 & 17.350 & 1.22 \\
\hline 1989 & 1480 & 1482 & 1.516 & 0.10 \\
\hline & & & & ERAGED 0.91 \\
\hline
\end{tabular}

The multiplier is used to explain the impact of one variable change in the model on other variables. Generally, we examine the impact of jovernment investment, which is variable independent of real GDE.

TABLE-4 MULTIPLIER EFFECTS
\begin{tabular}{lrrrrrrrrr} 
& 1 & 2 & 3 & 4 & 5 & 6 & 7 & 8 & 9 \\
\hline HOXKAIDO & 0.93 & 1.06 & 1.17 & 1.27 & 1.34 & 1.39 & 1.43 & 1.46 & 1.48 \\
REST OP JAPAN & 1.71 & 1.59 & 1.74 & 1.83 & 1.91 & 1.98 & 2.05 & 2.10 & 2.16
\end{tabular}

TABLE-4 refers to the multiplier effects of government investment on real GDE on both Hokkaido and the rest of Japan. According to the result, we can easily understand that the multiplier effects of Hokkaido are smaller than those of the rest of Japan. In the case of Hokkaido, multiplier effect in the first period is 0.93 which means that if the government adds \(¥ 1\) billion, real GDE is increased only \(¥ 0.93\) billion. It can be said that small multiplier effects mean that the effective demand leaks out to the rest of Japan by way of imports, as mentioned in the introduction.

\section*{VI-2 Baseline Projection (Most likely scenario)}

Next, we intend to forecast the performance of Hokkaido's economy with some scenarios. In the first place, we forecast the most likely scenario as a Baseline projection to the year 2000. Based on this Baseline projection, we can investigate the impact of policy simulations on the economies of both Hokkaido and the rest of Japan.

Based on the exogenous variables, in the three models: The macro model of the rest of Japan, the macro model of Hokkaido, and the I-O model of Hokkaido are calculated at the same time. APPENDIX B: Table \(1,2,3\) shows the results of the baseline projection. The average growth rate of real GDE in the rest of Japan is estimated to be \(2.8 \%\) during 1990-1995, 3.2\% during 1995-2000, or 3.0\% during the 1990's. This shows that the yearly average of the 1980's, 4.3\%, decreases to \(3.0 \%\) in the 1990 's.

As for the inflation rate, the annual average rate of inflation in terms of implicit deflator for GDE in the case of the rest of Japan will be \(0.7 \%\) for the 1990's, as a result of lower oil prices ( \(\$ 19 /\) barrel in \(1992, \$ 26 /\) barrel in 2000) and the appreciation of the yen against the US dollar ( \(¥ 126 / \$ \mathrm{US}\) in 1992 , \(¥ 110 / \$\) US in 2000 ) .

With regard to the trade balance, the Japanese trade surplus with the rest of the world will worsen towards 2000 , from US \(\$ 131\) billion in 1992 , to US \(\$ 180\) billion in 1995 , and US \(\$ 238\) billion in 2000.

In the case of Hokkaido, the annual average economic growth rate of real GDE is estimated at \(2.6 \%\) for the decade of 1990 's, or \(2.7 \%\) in the first half and \(2.6 \%\) in the latter half of the 1990 's. The yearly average growth rate of real GDE for the 1990's is \(0.5 \%\) points above that of the 1980's. This occurred especially after the 1989 economic growth rate of Hokkaido was accelerated by the rush of housing investment, expansion of non-housing investment by advancement of the companies into Hokkaido, and expansion of the tertiary sector by the rapid increase of tourists from the rest of Japan that was caused by the Heisei boom.

As compared with the past, it is expected that the Hokkaido economy will be bright in the future. The rate of population decrease will slow down, and the population will be 5.68 million in \(1990,5.64\) million in 1995 , and 5.58 million in 2000.

Regarding industrial activities, civil engineering and construction industries will remain dominant in Hokkaido, although the nature of the economy is changing gradually from government sector-oriented to private sector-oriented. The share of the output of those industries to the total output is expected to be \(13.0 \%\) in 1995 and \(13.3 \%\) in 2000 . However, the activity of manufacturing industries, such as the general machinery industry, the office and service machinery industry, and the electric machinery industry, will grow continuously. It can be said that advance of the high value-added-oriented industry will be progressing. At the same time, the share of the service industry will become larger and larger along with the size of the economy.

As a result, the share of the primary industry will decrease gradually, the share of the second industry will be stable, and the share of the tertiary industry will increase, from \(7.9 \%\) in 1990 to \(7.7 \%\) in 2000 , from \(39.6 \%\) to \(39.3 \%\), and from \(52.5 \%\) to \(53.1 \%\) respectively.

\section*{IV-3 Alternative Policy Simulations}

As mentioned above, the regional economy depends on national economic activity, especially on government expenditures for public works. The Hokkaido economy is also dependent on the economic climate of Japan and the policy of the Japanese government, as is the case with other regions.

Here, we intend to make two simulations based on scenarios and look into the nature of the Hokkaido economy and the future trend of the economy towards the year 2000.
A) \(¥ 430\) trillion government investment scenario:

In this scenario, we are going to investigate the impact of the expanded government investment on the Hokkaido economy which was presented in SII (Structural Impediments Initiative between Japan-US). According to the Baseline projection, it is expected that Japanese government investment in nominal terms will reach \(¥ 380\) trillion in total during the 1990’s. Therefore, this scenario is to elucidate the impacts of the \(¥ 50\) trillion expansion of government investment on the Hokkaido economy from 1992 to 2000.

In the total model system, the expansion of Japanese government investment affects Hokkaido public works directly by way of expansion of

Japanese public works as a whole. Indirectly an increase in government investment affects the Hokkaido economy through the expansion of exports from Hokkaido to the rest of Japan, which results from expansion of the Japanese GDP, and also the changes in the variables such as prices, wages, demographics, etc., in the model of the rest of Japan, which result from expanded Japanese government investment, affect the Hokkaido economy as well. According to the result of this simulation, as shown in Table \(1,2,3\) in the APPENDIX \(B\), the Hokkaido economy in terms of real GDE will be expanded by \(0.37 \%\) in 1995 and \(1.47 \%\) in 2000, and the average yearly growth rates of real GDE will be increased by 0.1\% point for the entire decade of the 1990's in comparison with the Baseline projection. On the other hand, in the case of the rest of Japan, the average annual growth rates of real GDE will be increased by \(0.2 \%\) point for the 1990 's, and the real GDE will be expanded by \(1.88 \%\) in 2000.

As for the population, since the impact on the Hokkaido economy will be larger than that on the rest of Japan, population outflow from Hokkaido to the rest of Japan will declined and population inflow will increase. The total population will increase by 724 people in 1995 and 2,563 people in 2000, as compared with the Baseline projection.

However, it is worth noting that the trade balance of Hokkaido will deteriorate by, in terms of 1985 real prices, \(¥ 80.8\) billion in 2000 , in comparison with the Baseline projection, because increase in exports resulting from the expansion of the economy of the rest of Japan will be smaller than increase in imports resulting from the economic expansion of Hokkaido. Regarding the sectoral economy, it is expected that some industries which heavily depend on public works, such as civil engineering, construction, office-service equipment, general machinery, cement and other ceramics, will be affected remarkably by this scenario (see Table 2 in APPENDIX B).

In view of the results of this simulation, it can be seen that the Hokkaido economy is gradually progressing to a high value-added-oriented economy, but it is still heavily dependent on government sector in nature.
B)Vitalized economy by private sector scenario:

In this scenario, we intend to calculate the vitalization impact on the Hokkaido economy by changing the investment from government expenditure-oriented to the high value-added-oriented. In order to carry out
this scenario simulation, we hypothesize three factors as follows: (1)government investment is to be cut in half (50\%) in comparison with the Baseline projection, (2)the private non-housing investment is to be increased by the amount of government investment cut in (1), and (3) the share of civil engineering and construction sectors within the fixed capital formation in the Final Demand of the I-O Model is to be reduced by half, and the share of processing and assembling in the manufacturing sector is to be increased consistently (share total \(=1.0\), see TABLE-5).

TABLE-5 SHARE OF FIXED CAPITAL FORMATION BY INDUSTRY
\begin{tabular}{|c|c|c|c|c|c|c|c|c|c|}
\hline \multicolumn{2}{|l|}{\multirow[t]{3}{*}{}} & \multicolumn{2}{|l|}{Hiixcpif C P} & \multicolumn{6}{|l|}{SUM (GFCF)} \\
\hline & & & & 1.0351881 & & & & & \\
\hline & & C P & C G & GFCF & 115 & E X & BASE & SCENARIO & SCN/BAS \\
\hline 1 & Agricultural & 6. 017290 & B. 800808 & A. 115695 & 0. 748465 & 0. 130857 & 0.015695 & D. 015695 & 1. 08 \\
\hline 2 & Forestry & 0.001049 & 0.000000 & 0.080008 & -0.027703 & 0.084107 & 0 & 0 & \\
\hline 3 & Fishing & B. 005871 & 0. 808808 & 0. 888080 & -0.086362 & 0. 041180 & 0 & 0 & \\
\hline 4 & Mining - & -0.000054 & 0. 000080 & 0.008080 & 0.168471 & 0. 018899 & 0 & 0 & \\
\hline 5 & Beveroge \& Tabacc & 0.152308 & 0.000008 & 0.000800 & B. 737375 & D. 3238 E 2 & 8 & 0 & \\
\hline 6 & Fabricatod textil & 0. 836776 & 0.006888 & B. 804454 & 0.018778 & 0.083409 & 0.004454 & 0.004454 & 1.00 \\
\hline 7 & Lumbor, Wooden & D. 008592 & 0.008008 & 0.000351 & 0.050722 & 0.032428 & 0.000351 & O. 080351 & 1.00 \\
\hline 8 & Furnituro & 0. 003683 & 0.880080 & 0.808828 & D. 085921 & 0.009417 & B. 008828 & 0.008828 & 1.00 \\
\hline 9 & Puld 8 Paper & D. 280738 & 0.080808 & 0.808808 & D. 268855 & 0. 096843 & 0 & 0 & \\
\hline 10 & Publish. \& Print. & C. 088479 & 0.080000 & 0.000000 & -8. 806583 & 0.085975 & 0 & 0 & \\
\hline 11 & Chemical & 0. 114280 & 0.000000 & 8.888888 & -6. 813697 & 0. 609885 & 0 & 0 & \\
\hline 12 & Potroleum & B. 026261 & 0. 800808 & 0.000800 & 0. 154987 & 0. 083232 & 0 & 0 & \\
\hline 13 & Plastic & 0.002490 & 0. 000008 & 0.008000 & -0.881816 & B. 882724 & 0 & \(B\) & \\
\hline 14 & Rubber & 0.883182 & 0.008000 & 0.088086 & 0. 023373 & 0. 881237 & 8 & \(\square\) & \\
\hline 15 & Loather & B. 003684 & 0.000088 & 0. 000000 & -0.006981 & 0.001629 & 0 & 0 & \\
\hline :6 & Coramic, stono & 0. 802249 & 0.000008 & 0.800008 & 0.013299 & 0.088212 & 0 & 0 & \\
\hline : 7 & Steel & 0.880688 & 0.000088 & 6. 000000 & 0.411435 & 0.044972 & 0 & 8 & \\
\hline 18 & Non-ferrous metal & D. 881665 & 0.080808 & 0.008008 & 0.021128 & 0.085858 & 0 & 0 & \\
\hline : 9 & Other metals & 0.082899 & 0.080880 & 0.805798 & 0. 385572 & D. 018264 & 0.005790 & 0.005790 & 1.00 \\
\hline 20 & Goneral machinery & 0.000027 & 0.000800 & 0. 057968 & 0. 336102 & D. 015847 & B. 857968 & D. 153758 & 2.65 \\
\hline 21 & office machinery & 0.000098 & 0.000000 & 0.011861 & 0. 135656 & 0.006008 & B. 811861 & D. 031460 & 2.65 \\
\hline 22 & Household mach. & 0. 015549 & 0.008008 & 0. 011831 & 0. 158485 & 0.801667 & D. 011831 & 0.031380 & 2.65 \\
\hline 23 & Electronic equid & 0.001070 & 0.000000 & 0.053959 & 0.092652 & 0.814160 & D. 053959 & D. 143123 & 2.65 \\
\hline 24 & Other elec'mach. & 0.006138 & 0.000000 & 0. 023038 & 0. 115893 & 0. 007568 & 0. 823038 & 0.061107 & 2.65 \\
\hline 25 & Cars & 0. 826925 & 0. 080088 & 0. 032796 & 0. 234569 & 0. 005678 & 0. 832796 & 0.886990 & 2.65 \\
\hline 26 & Other transport. & 0.000595 & 0.000000 & 0. 017690 & -0.288296 & 0.008623 & 0. 017698 & D. 046921 & 2. 65 \\
\hline 27 & Parts 8 access. & 0.083738 & 0.000080 & 0.007581 & 0.155967 & D. 008927 & 0.007581 & 0.020109 & 2.65 \\
\hline 28 & Other manufacture & 0.011355 & 0.080000 & 0.006777 & 0.082121 & 0.008474 & 0. 006777 & 0. 817975 & 2. 65 \\
\hline 29 & Construction & 0.080000 & 0.000000 & 0.346768 & 0.000008 & 0.008800 & D. 346768 & D. 173384 & 0.50 \\
\hline 30 & Civil engineering & 0.000000 & 0.000000 & D. 391877 & 0.080008 & 0. 868088 & 0. 391877 & D. 195938 & 0.58 \\
\hline 31 & Eloctricity & 0.017894 & 0.080008 & 0.000080 & 0.000000 & D. 001023 & 0 & 1 & \\
\hline 32 & Gas & 0.003123 & 0.080000 & 0.000000 & 0.000000 & 0.000018 & 0 & 0 & \\
\hline 33 & City water \& sani & 0.007151 & 0.039816 & 0.080880 & 0.080080 & 0. 000018 & 0 & 0 & \\
\hline 34 & Commerce & 0. 210755 & 0.800008 & 0. 033751 & 0. 444926 & 0. 133527 & 0.033751 & 0.033751 & 1.00 \\
\hline 35 & Finance 8 Insuran & 0.028636 & 0. 000000 & 0. 000080 & 0.000080 & 0.080954 & 0 & 0 & \\
\hline 36 & Real estate & 0. 135268 & 0.000000 & 0. 000888 & 0.000008 & 0. 100063 & 0 & 8 & \\
\hline 37 & Irsisport & 0.054627 & 0. 000041 & 0. 004173 & 0.099898 & 0. 096954 & 0.004173 & 0.004173 & 1.80 \\
\hline 38 & Communc. \& Broad & 0.017154 & 0.000000 & 0.000000 & 0.080088 & B. 012898 & \(\square\) & 0 & \\
\hline 39 & Government & 0.082386 & 0.699129 & 0. 000080 & 0.600008 & 0.000080 & 0 & 0 & \\
\hline 40 & Educat.8 Research & 0.016304 & D. 311764 & 0. 280000 & 0.000000 & 0.000143 & 0 & 0 & \\
\hline 41 & Medical 8 Health & 0.125073 & 0.057408 & 0. 000880 & 0.800888 & 0.080081 & 0 & 0 & \\
\hline 42 & Non-profit serv. & D. 013680 & 0.008088 & 0. 280888 & 0.000080 & 0. 013380 & 0 & 8 & \\
\hline 43 & Business serv. & 0.081600 & 0.000800 & 0. 000008 & 0.800008 & 0.003506 & 0 & 0 & \\
\hline 44 & Personal serv. & D. 176133 & 0.000000 & 0.000000 & 0.800080 & B. 068596 & 0 & 0 & \\
\hline 45 & Unclassified & 0.080000 & 0.000000 & 0. 080008 & 0.000080 & 0.027515 & 0 & 0 & \\
\hline
\end{tabular}

By this scenario, we elucidate the impacts of the difference of multiplier effects stimulated by government investment and by private non-housing investment in the macro model and the impact caused by the changes in Final Demand on the sectoral output in the I-O model.

According to the result of this scenario simulation, as shown in Table 3 in the APPENDIX B, it is expected that the Hokkaido economy in real GDE will be expanded by \(1.47 \%\) in 1995 and by \(2.50 \%\) in 2000 , and the total population will decrease by 15,516 people in 1995 and by 29,029 people in 2000, in comparison with the Baseline projection.

It is noteworthy that wage rates will increase by \(2.99 \%\) in 1995 and by \(5.18 \%\) in 2000, and inflation rates will decline by \(1.37 \%\) in 1995 and \(2.35 \%\) in 2000, through improved labour productivity in Hokkaido, compared with the Baseline projection.

As for the sectoral economy, it is expected that manufacturing industries, such as general machinery, automobile, office and service equipment, electric machinery, etc., will be strengthened in comparison with the Baseline projection, which will result in the expansion of the macro economy through the equation of the Converter Matrix between the macro model and the I-O model, while the economic activity of civil engineering and construction industries will be damaged, and some industries which are strongly related to them will be affected negatively.

As a result of this scenario simulation, it can be seen that shifting from the government-oriented economy to private sector-oriented economy will enable Hokkaido not only to expand its economy, but also to improve its economic nature from dependent to independent.

\section*{V Concluding Remarks}

In this study, we linked the HOKKAIDO MACRO I-O INTEGRATED MODEL with the macro model of the rest of Japan, and analyzed the Hokkaido economic structure with two scenario simulations. It can be seen from the study that the Hokkaido economy is still heavily dependent on government expenditure, even though the economy is progressing to a high value-added-oriented economy.

On the other hand, Japan will face an increasingly aging society in
the near future, and therefore, the labour power shortage is becoming very crucial for future economic activity (Nakamura, 1992). In view of Japan's current economic circumstances, the regional economy will become much more important with the expansion of the Japanese economy.

In the near future, we intend to improve the model by endogenizing Aij in the I-O model (S. Shishido and O. Nakamura, 1992) by dividing Hokkaido into four sub-regions linked with FOUR REGIONAL I-O TABLES OF HOKKAIDO, which was published by the Hokkaido Development Agency in 1992, and by making a MULTI-SECTORAL MODEL OF HOKKAIDO.

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APPENDIX A: Hokkaido Macro-econometric Model Variables \& Model Specifications

VARIABLES
\begin{tabular}{|c|c|c|c|c|}
\hline VARIABLES & \[
\begin{aligned}
& \text { END } \\
& \text { /EXO }
\end{aligned}
\] & UNIT & REAL & <maCRO variables> definition \\
\hline \(\overline{\text { AMI }}\) & END & 1 thousand cars & REAL & Nunber of automobile \\
\hline CG & END & 1 -illion Yen & NOMI & Governsent final consumption expenditure \\
\hline CCC & END & 1 dillion Yen & NOMI & Governsent final consumption expenditure, Central \\
\hline \({ }^{\text {CGL }}\) & END & 1 Eillion Yen & NOHI & Government final consumption expenditure, Local \\
\hline CGM & END & 1 million Yen & NOHI & Government final consumption expenditure, Municipal \\
\hline CP & END & 1 (illion Yen & NOHI & Private final consumption expenditure \\
\hline CPD & END & 1 nillion Yen & NOMI & Domestic consumption \\
\hline CPI & END & 1985=100 & & Consuner price index \\
\hline DSLBHP & END & 1 aillion Yen & NOMI & Banks loan for private housing \\
\hline E & END & 1 nillion Yen & NOHI & Export of goods and services \\
\hline GB & END & 1 nillion Yen & NOMI & Balance on Public Finance \\
\hline GDE & END & 1 nillion Yen & NOMI & Gross Domestic Product of Hokkaido \\
\hline IG & END & 1 million Yen & NOMI & Government fixed investment \\
\hline IPC & END & 1 dillion Yen & NOHI & Private non-residential investment \\
\hline IPH & END & 1 nillion Yen & NOHI & Private residential investment \\
\hline IRC & END & * & & JAPAN: Call momey rate \\
\hline IRIX & EXO & \% & & JAPAN: Official rate \\
\hline IRP & END & \% & & JAPAN: Prime rate \\
\hline JG & END & 1 nillion Yen & NOMI & Increase in stocks, Government \\
\hline JP & END & 1 nillion Yen & NOHI & Increase in stocks, Private \\
\hline JCPI & END & 1985=100 & & REST Of JAPAN MACRO MODEL: Wholesale price index \\
\hline JIG & END & 1 billion Yen & REAL & REST OF JAPAF MACRO MODEL: Public fixed investment \\
\hline JLDH & END & & & REST OP JAPAN MACRO MODEL: Effective job openings \\
\hline JPCG & END & 1 billion Yen & REAL & REST Of JAPAN MACRO MODEL: IEplicit deflator for CG \\
\hline \({ }^{\text {JPCP }}\) & END & 1 billion Yen & REAL & REST Of JAPAN MACBO MODEL: Implicit deflator for CP \\
\hline JPIG & END & 1 billion Yea & REAL & REST OP JAPAN MACRO MODEL: Implicit deflator for IG \\
\hline JPIPC & END & 1 billion Yen & REAL & REST Of JAPAN MACRO MODEL: Implicit deflator for IPC \\
\hline JPIPH & END & 1 billion Yen & bRAL & REST OF JAPAN MACRO MODEL: Implicit deflator for IPH \\
\hline JRGNP & END & 1 billion Yen & REAL & REST Of Japan macko model: Gross national product \\
\hline JWPI & END & 1985=100 & & REST OP JAPAN MACRO MODEL: Consumer price index \\
\hline JXGLF & END & 1 nillion Yen & NOMI & REST OF JAPAN MACRO MODEL: Local finace expenditure \\
\hline JXGPM & END & 1 illion Yen & NOHI & REST OF JAPAN MACRO MODEL: Public works expenditure \\
\hline LDM & END & & & Effective job openings \\
\hline LEN & END & person & & Number of employed \\
\hline LN & END & person & & Labour force \\
\hline \({ }^{\text {LPI }}\) & END & 1985=100 & & Labour productivity index \\
\hline \({ }_{\text {LIN }}\) & END & person & & Number of unemployed \\
\hline LUR & END & & & Unemployment rate \\
\hline LWN & END & person & & Number of enployees \\
\hline M & END & 1 nillion Yen & HOMI & Inport of goods and services \\
\hline OA & EXO & 1 nillion Yen & NOHI & Indutrial production of agriculture Ind. \\
\hline \({ }^{0}\) & ExO & 1 nillion Yen & NOMI & Indutrial production of fishery Ind. \\
\hline PCG & END & 1985=100 & & Inplicit deflator for CG \\
\hline PCP & END & 1985=100 & & Inplicit deflator for CP \\
\hline PE & END & 1985=100 & & Price of export \\
\hline PGDE & END & 1985=100 & & Implicit deflator for GDE \\
\hline PIG & END & 1985=100 & & Implicit deflator for IG \\
\hline PIPC & END & 1985=100 & & Implicit deflator for IPC \\
\hline PIPH & END & 1985=100 & & Inplicit deflator for IPH \\
\hline PM & END & 1985=100 & & Price of import \\
\hline
\end{tabular}
\begin{tabular}{|c|c|c|}
\hline POP & END & person \\
\hline POPB & END & person \\
\hline POPBR & EX0 & \\
\hline POPD & END & person \\
\hline POPDR & EX0 & \\
\hline POPIN & END & person \\
\hline POPOUT & END & person \\
\hline PSTOCX & END & 1968=100 \\
\hline BCGC & END & 1 nillion Yen \\
\hline RCGL & END & 1 nillion Yen \\
\hline RCGM & END & 1 ■illion Yen \\
\hline RCP & END & 1 -illion Yen \\
\hline RDFC & END & 1 million Yen \\
\hline RE & END & 1 -illion Yen \\
\hline RGDE & END & 1 million Yen \\
\hline RGDEC & END & 1 ■illion Yen \\
\hline RIG & END & 1 ©illion Yen \\
\hline BIPC & END & 1 ©illion Yen \\
\hline RIPH & END & 1 ■illion Yen \\
\hline RJG & END & 1 nillion Yen \\
\hline RJP & END & 1 Iillion Yen \\
\hline RKPC & END & 1 nillion Yen \\
\hline RM & END & 1 İllion Yen \\
\hline RSD & EX0 & 1 million Yen \\
\hline SD & EX0 & 1 ©illion Yen \\
\hline SXGCD & EXO & \\
\hline TAM & END & 1 Eillion Yen \\
\hline TYCI & END & 1 ■illion Yen \\
\hline TYCP & END & 1 ■illion Yen \\
\hline TYLG & END & 1 ■illion Yen \\
\hline TYMG & END & 1 nillion Yen \\
\hline TYW & END & 1 nillion Yen \\
\hline VGL & END & 1 aillion Yen \\
\hline VGLB & END & 1 nillion Yen \\
\hline VGLC & END & 1 ■illion Yen \\
\hline VGLO & END & 1 nillion Yen \\
\hline VGLT & END & 1 dillion Yen \\
\hline W & END & 1 nillion Yen \\
\hline HI & END & 1985=100 \\
\hline XGCD & END & 1 nillion Yen \\
\hline XGCDA & END & 1 Eillion Yen \\
\hline XGCDH & END & 1 nillion Yen \\
\hline XGCDR & END & 1 aillion Yen \\
\hline XGL & END & 1 nillion Yen \\
\hline XGLAAL & END & 1 nillion Yen \\
\hline XGLE & END & 1 million Yen \\
\hline XGLX & END & 1 million Yen \\
\hline XGLO & END & 1 nillion Yen \\
\hline XHSH & END & 1 ■illion Yen \\
\hline YAH & END & 1 aillion Yen \\
\hline YAHD & END & 1 nillion Yen \\
\hline YAHI & END & 1 nillion Yen \\
\hline YAHR & END & 1 ®illion Yen \\
\hline YCI & END & 1 ■illion Yen \\
\hline YCIA & END & 1 ■illion Yen \\
\hline YCII & END & 1 ■illion Yen \\
\hline
\end{tabular}

\footnotetext{
Population
Population of births
Birth rate ( \(\mathrm{POPB} / \mathrm{POP}\) )
Population of deaths
Death rate (POPD/POP)
Inflow of population
Outflow of population
JAPAN: Stock price index in Tokyo market
REAL Governeent final consumption expenditure, Central
REAL Governeent final consumption expenditure, Local
REAL Governeent final consuption expenditure, Municipal
REAL Private final consumption expenditure
BEAL Depreciation of non-housing capital
REAL Export of goods and services
REAL Gross Domestic Product of Hokkaido
REAL Production potentiality
REAL Public fixed investment
REAL Private non-residential investment
REAL Private residential investment
BEAL Increase in stocks, Government
REAL Increase in stocks, Private
REAL Capital stock, private corporate sector
BRAL Imports of goods and services
RAEL Statistic discrepancy
NOMI Statistic discrepancy
XGCD' s share with total public works
NOMI Tax on automobile holding
NOMI Tax on private business
NOMI Corporate direct tax
NOHI Residents' tax, Local
NOMI Residents' tax, Municipal
NOMI Personal income tax
NOMI Public finance revenue, Total
NOMI Public finance revenue fron Bond
NOMI Public finance revenue from Central government subsidy
NOMI Public finace revenue from Other
NOMI Piublic finance revenue from Tax revenue
NOMI Hage per employee
Hage index of regular workers
NOMI Hokkaido Development Budget, Total
NOMI Hokkaido Developaent Budget for Agriculture
NOMI Hokkaido Development Budget for Housing
NOMI Hokkaido Development Budget for Road
NOMI Public finance expenditure, Total
NOMI Public finance expenditure for Agriculture
NOMI Public finance expenditure for Constructing
NOMI Public finance expenditure for Education
NOMI Public finance expenditure for Others
NOMI Contribution to social insurance, household
NOMI Property incone of household
NOMI Property income of household, Dividend
NOMI Property income of household, Interest
NOMI Property income of household, Rent
NOMI Proprietor's incone
NOMI Proprietor's incone, Agriculture, forestry, and fisheries
NOMI Proprietor's income, Trade and industries
}
\begin{tabular}{lllll} 
YCIR & END & 1 million Yen & NOMI & Proprietor's income, Rent and lease \\
YCP & END & 1 villion Yen & NOMI & Corporate income \\
YD & END & 1 million Yen & NOMI & Household disposal income \\
YP & END & 1 million Yen & NOMI & Household income \\
YW & END & 1 million Yen & NOMI & Hage income of employees
\end{tabular}
\begin{tabular}{|c|c|c|c|c|}
\hline \multirow[t]{2}{*}{VARIABLES} & & UNIT & REAL & \multirow[t]{2}{*}{<SECTORAL VABIABLES> definition} \\
\hline & /EXO & & NOMI & \\
\hline \(\overline{\text { XIIPT }}\) & END & 1 million Yen & NOMI & Industrial production of total Industry \\
\hline XIIPST & END & 1 aillion Yen & NOHI & Industrial production of iron \& steel Ind. \\
\hline XIIPMC & END & 1 aillion Yen & NOMI & Industrial production of nachinery Ind. \\
\hline XIIPCM & END & 1 nillion Yen & NOMI & Industrial production of chenical product Ind. \\
\hline XIIPOC & END & 1 nillion Yen & NOMI & Industrial production of oil \& coal Ind. \\
\hline XIIPPP & END & 1 nillion Yen & NOMI & Industrial productiou of paper \& pulp Ind. \\
\hline XIIPCE & END & 1 nillion Yen & NOMI & Industrial production of cement Ind. \\
\hline XIIPPT & END & 1 Eillion Yen & NOMI & Industrial production of food Ind. \\
\hline XIIPTP & END & 1 dillion Yen & NOHI & Industrial production of textile Ind. \\
\hline XIIPMI & END & 1 nillion Yen & NOMI & Industrial production of eining Ind. \\
\hline PUIIPT & END & 1 nillion Yen & NOMI & lnput-price for total Industry \\
\hline PUST & END & 1 nillion Yen & NOMI & Input-price for iron \& steel Ind. \\
\hline PUMC & END & 1 صillion Yen & NOMI & Input-price for machinery Ind. \\
\hline PUCM & END & 1 nillion Yen & NOMI & Input-price for chenical product Ind. \\
\hline PUOC & END & 1 nillion Yen & NOMI & Input-price for oil \& coal Ind. \\
\hline PUPP & END & 1 -illion Yen & NOMI & Input-price for paper \& pulp Ind. \\
\hline PUCE & END & 1 nillion Yen & HOHI & Input-price for cerent Ind. \\
\hline PUPT & END & 1 nillion Yen & NOMI & Input-price for food Ind. \\
\hline PUTP & END & 1 aillion Yen & NOMI & Input-price for textile Ind. \\
\hline PVMI & END & 1 aillion Yen & NOMI & Input-price for mining Ind. \\
\hline PXIIPT & END & 1 sillion Yen & NOHI & Output-price for total Industry \\
\hline PXST & END & 1 nillion Yen & NOMI & Output-price for iron \& steel Ind. \\
\hline PXMC & END & 1 nillion Yen & NOMI & Output-price for eachinery Ind. \\
\hline PXCM & END & 1 nillion Yen & NOMI & Output-price for chenical product Ind. \\
\hline PXOC & END & 1 tillion Yen & NOMI & Output-price for oil \& coal Ind. \\
\hline PXPP & END & 1 nillion Yen & NOMI & Output-price for paper \& pulp Ind. \\
\hline PXCE & END & 1 nillion Yen & NOMI & Output-price for cement Ind. \\
\hline PXFT & END & 1 dillion Yen & NOMI & Output-price for food Ind. \\
\hline PXTP & END & 1 Eillion Yen & NOMI & Output-price for textile Ind. \\
\hline PXMI & END & 1 sillion Yen & NOMI & Output-price for nining Ind. \\
\hline IIPT & END & 1985=100 & & Industrial production index for total Industry \\
\hline IIPST & END & 1985=100 & & Industrial production index for iron \& steel Ind. \\
\hline IIPMC & END & 1985 \(=100\) & & Industrial production index for machinery Ind. \\
\hline IIPCM & END & 1985=100 & & Industrial production index for chenical product Ind. \\
\hline IIPOC & END & 1985=100 & & Industrial production index for oil \& coal Ind. \\
\hline IIPPP & END & 1985=100 & & Industrial production index for paper \& pulp Ind. \\
\hline IIPCE & END & 1985=100 & & Industrial production index for cement Ind. \\
\hline IIPFT & END & 1985=100 & & Industrial production index for food Ind. \\
\hline IIPTP & END & 1985=100 & & Industrial production index for textile Ind. \\
\hline IIPMI & END & 1985=100 & & Industrial production index for mining Ind. \\
\hline
\end{tabular}
A. PUBLIC PINANCE SECTOR
1. Revenue

VGL \(=V G L T+V G L C+V G L B+V G L 0\)
2. Tax Revenue
\(\mathrm{VGLT} \stackrel{\text { Re }}{=} 120486+0.039221\) *GDE
Sa■ple \(\begin{array}{cc}\left(\begin{array}{c}-7.78) \\ 1976-1989\end{array}\right. & \text { RRADJ }=0.98567\end{array}\) S.E. \(=11201.90 \quad\) D.H. \(=1.464\)
3. Central Government Subsidy

4. Bond Revenue
```

VGLB $=+27119.7+1.44082 * \operatorname{XGLE}(-1)-0.26712 * X G C D(-1)$
Sample 1976-1989 RRADJ=0.89749 S.E. $=266 \mathrm{i} 8.30 \quad$ D.W. $=1.595$

```
5. Other Revenue
```

VGLO $=-8037.07+0.0095888 * G D E(-1)+0.63013 * V G L 0(-1)$
Sample 1976-1989 RRADJ=0.95777 S.E. $=14167.70$ D.H. $=1.425$

```
6. Japan Public Horks Expenditure

7. Hokkaido Developent Budget, Total
\(X G C D=S X G C D * J X G P\)
8. Hokkaido Development Budget, Agriculture

Sample 1976-1989 RRADJ \(=0.94272\) S.E. \(=6673.24\) D.H. \(=0.967\)
9. Hokkaido Development Budget, Road

XGCDR \(=+17884.5+0.33907 * X G C D-0.12381 * X G C D R(-1)\)
Sample \(1976-1989\) RRÁdJ \(\begin{gathered}8.76) \\ 0.97205\end{gathered} \quad\) S.E. \(=6096\)
10. Hokkaido Development Budget, Housing

XGCDH \(=-9854.86+0.0964950 * X G C D+0.16511 * X G C D H(-1)\)

Sample 1976-1989 RRADJ \(=0.99591\) S.E. \(=905.09\) D.K. \(=2.029\)
11. Expenditure
\(X G L=X G L A A L+X G L X+X G L E+X G L O\)
12. Expenditure for Agriculture

XGLAAL \(=+15737.2+8.10141 * Y C I A(-1)+0.74693 *\) XGLAAL \((-1)\)
Sapple 0.078 ( 2.11 ) ( 9.06 )
D. H. \(=1.380\)
13. Expenditure for Education

XGLK \(=+46734.9+0.0476271 * V G L+0.73143 * \operatorname{XGLK}(-1)\)
Saصple \(1976-1989 \quad\) RRADJ \(=04)\)
14. Expenditure for Constructing
\(X G L E=-38169.6+0.20755 * V G L-0.11012 * X G C D(-1)\)
Sample 1976-1989 RRADJ=0.98341 S.E. \(=9607.02\) D.W. \(=1.737\)
```

15. Expenditure for Others
$X G L O=-126669+0.54917 * V G L$
(-3.86) (28.56)
Sample 1976-1989 RRADJ $=0.98430$ S.E. $=290004.20$ D.H. $=0.960$
16. Balance on Public Finance
$G B=X G L-V G L$
```

\section*{B. POPUlation, labour porce sector}
```

1. Total Population
$P O P=P O P(-1)+P O P B-P O P D+P O P I N-P O P O U T$
2. Population of Births
$\mathrm{POPB}=\mathrm{POPBR} * \mathrm{POP}$
3. Population of Deaths
POPD $=$ POPDR*POP
```
```

4. Inflow of Population
```
4. Inflow of Population
\(\operatorname{LOG}(\) POPIN \()=+\underset{(2.93345}{2.44)}+\underset{2}{0.31566 * L O G(L D M)}-\underset{2}{0.11455 * L O G(J L D H})\)
\(\operatorname{LOG}(\) POPIN \()=+\underset{(2.93345}{2.44)}+\underset{2}{0.31566 * L O G(L D M)}-\underset{2}{0.11455 * L O G(J L D H})\)
    \(\left.+\begin{array}{c}0.75639 * L O G(P O P I N \\ 7.40)\end{array}(-1)\right)\)
    \(\left.+\begin{array}{c}0.75639 * L O G(P O P I N \\ 7.40)\end{array}(-1)\right)\)
Saゅple 1976-1989 BRADJ=0.93768 S.E. \(=0.02\) D.H. \(=2.539\)
5. Outflow of Population
```



```
\(\left.\left.+\begin{array}{c}0.45703 * L O G(L D M / J L D M \\ 2.62)\end{array}\right)+\begin{array}{c}0.53061 * \operatorname{POPOUT}(-1) \\ 3.00\end{array}\right)\)
Sanple 1976-1989 RRADJ=0.72980 S.E. \(=0.03\) D. \(\mathrm{H} .=1.328\)
6. Labour Porce
```



```
Sanple 1976-1989 RRADJ=0.94594 S.E. \(=18963.10 \quad\) D.H. \(=1.285\)
7. Effective Job Openings
```




```
Sample 1976-1989 RRADJ \(=0.90848\) S.E. \(=0.04\) D..\(=1.222\)
8. Number of Unemployed
\(\operatorname{LOG}(\mathrm{LUN})=+48.0642-2.97801 * \operatorname{LOG}(\) RGDE \()+2.12950 * \operatorname{LOG}(\mathrm{HI}(-1))\)
\(+(6.07)\left(\begin{array}{l}-5.78) \\ +0.98)\end{array}\right.\)
\(+\underset{\binom{0.22667 * \operatorname{LOG}(\operatorname{LUN}(-1)}{1.11)}}{ }\)
Sample \(1976-1989\) BRADJ \(=0.91421\) S.E. \(=0.06\) D.H. \(=2.238\)
9. Number of Employees
```




```
Sample 1976-1989 RRADJ \(=0.99798\) S.E. \(=0.00\) D. H. \(=2.219\)
10. Unemployment Rate
LUR \(=\) LUN/LN*100
11. Number of Enployers and Employees
\(\mathrm{LEN}=\mathrm{LN}-\mathrm{LUN}\)
```

C. real expenditure sector

```
1. Private Final Consumption Expenditure
\(\mathrm{RCP}=+741665+0.161567 * Y \mathrm{D} / \mathrm{PCP} * 100\)
    (0.59) (0.81)
    \(-89980.6 *(\) IRC \()+0.85483 * R C P(-1)\)
    Sample 1978-1989 RRADJ=0.97655 S.E. \(=150086.00 \quad\) D.H. \(=2.605\)
```

2 Government Final Consumption Expenditure, Central
RCGC = CGC/PCG*100
3. Governaent Final Consumption Expenditure, Local
RCGL = CGL/PCG*100
4. Government Final Consumption Expenditure, Municipal
RCGM = CGH/PCG*100
5. Governaent Pinal Consumption Expenditure
RCG $=$ RCGC + RCGL + RCGM
6. Private Non-residential Investrent
RIPC $=+115784+0.0578426$ (RGDE+RGDE $(-1))$
$+(0.25)(4.54)$
$+22.2701 *(X G C D+X G L A A L+X G L E) / P C G * 100$
(1.22)
- $31361.2 * \operatorname{IRP}(-1)$
Sauple $1976-1989$ RRADJ $=0.90486$ S.E. $=67738.70 \quad$ D.W. $=1.377$
7 Private Residential Investuent
RIPH $=+216778+27.9703 *((Y P-C P) / P C P+(Y P(-1)-C P(-1)) / P C P(-1))$
$-\quad(25732.5 * \mathrm{IRK}$ ( 10.38 )
- $35732.5 *$
$+\begin{gathered}-4.99) \\ +0.72203 *(\mathrm{M} 2 \mathrm{CD}+\mathrm{H} 2 C D(-1)) \\ 7.26)\end{gathered}$
Sample 1976-1989 RRADJ $=0.89655$ S.E. $=30569.90 \quad$ D.W. $=2.537$
8. Public Fixed Investment
RIG = IG/PIG*100
9. Increase in Stocks, Private
$R J P=-4132 E+03+1229 E+03 *(X G C D / P G D E) /(X G C D / P G D E+X G C D(-1) / P G D E(-1))$
(-3.79) (1.70)
$+7013 \dot{\mathrm{E}}+03 * \mathrm{CPI} /(\mathrm{CPI}+\mathrm{CPI}(-1))$
$\binom{3.26)}{3.291}$
Sample 1976-1989 RRADJ=0.51738 S.E. $=58278.20$ D.W. $=1.997$
10. Increase in Stocks, Government
RJG $=-1987 \mathrm{E}+03-0.25271 * \mathrm{RJP}+3883 \mathrm{E}+03 * \mathrm{RGDE} /(\mathrm{RGDE}+\mathrm{RGDE}(-1))$
$(-1.87)(-1.42)\left(\begin{array}{r}(1.85)\end{array}\right.$
$+0.4001 .65 * D 0 T(X G C D)$
Sample 1976-1989 RRADJ=0.57813 S.E. $=43594.70$ D.W. $=1.403$
11. Export of Goods and Services


12. Imports of Goods and Services
$\mathrm{RM}=+2465 \mathrm{E}+03+0.34090 * \mathrm{RGDE}-8166.27 * \mathrm{PM}(-1)$

13. Gross Donestic Expenditure of Hokkaido, Real Tera
$R G D E=R C P+R C G+R I P C+R I P H+R I G+R J P+R J G+R E-R M+R S D$

## D. real production sector

```
1. Production Potentiality
\(\operatorname{LOG}(\mathrm{RGDEC})=+1.32497+0.36803 * \mathrm{LOG}(\mathrm{RKPC})+0.60360 * \mathrm{LOG}(\mathrm{LN})\)
Sample 1976-1989 RRADJ=0.94544 S.E. \(=0.03\) D.H. \(=1.085\)
2. Capital Stock, Private Corporate Sector
RKP \(=\operatorname{RKP}(-1)+\) RIPC \(-\operatorname{RDFC}\)
3. Depreciation of Non-housing Capital
```

```
RDFC}=+4724.77+0.11038**RRP
```

RDFC}=+4724.77+0.11038**RRP
Sample 1976-1989 RRADJ=0.99428 S.E.=27533.00 D.H.=2.052

```
Sample 1976-1989 RRADJ=0.99428 S.E.=27533.00 D.H.=2.052
```

4. Labour Productivity Index

LPI $=($ RGDEC $/ L N) /($ RGDEC. $85 / L N .85)$

## E. PRICE SECTOR

```
1. Consumer Price Index
\(\operatorname{LOG}(C P I)=-0.13333+1.11245 * L 0 G(J C P I)-0.25629 * L 0 G(R G D E C / L N))\)
Sample 1976-1989 BRADJ=0.99754 S.E. \(=0.01 \quad\) D. \(\quad\) H. \(=1.019\)
```

```
2. Implicit Deflator for CP
```



```
Sample 1976-1989 RRADJ \(=0.99682\) S.E. \(=0.01\) D.W. \(=0.971\)
```

3. Implicit deflator for CG

```
Sanple 1976-1989 RRADJ \(=0.98369\) S.E. \(=0.02\) D. W. \(=1.189\)
```

4. Implicit Deflator for IPC

Sample 1976-1989 RRAD $=1.00 \quad$ S.E. $=0.00$ D.W. $=2.583$
5. Implicit Deflator for IPH
$\mathrm{LOG}(\mathrm{PIPH})=-\underset{(-0002967}{-0.85)}+\underset{(1.00006 * \operatorname{LOG}(J P I P H)}{13064.30)}$
Sample 1976-1989 RRADJ=1.00 S.E. $=0.00$ D.W. $=1.574$
```
6. Implicit Deflator for IG
LOG(PIG) = - 0.0071769 + 1.00168*L0G(JPIG)
    Sample 1976-1989 RRADJ=0.99991 S.E.=0.00 D.N. =1.535
```

```
#.0.Price of Export 
```

8. Price of Inport

Sample 1976-1989 RRADJ $=0.93854 \quad$ S.E. $=0.02 \quad$ D. W. $=0.708$
g. Implicit Deflator for GDE

PGDE $=$ GDE/RGDE*100

## F. NOMINAL EXPENDITURE SECTOR

 $C P=R C P * P C P / 100$

```
2. Government Final Consumption expenditure, Central
CGC = +62140.2+2.93377*JXGLF(-1) + 0.85143*CGC(-1)
    (1.74) (0.64) ( 5.38)
    Sample 1976-1989 RRADJ=0.97731 S.E.=11462.20 D.N. =1.959
```

```
3. Government Final Consumption Expenditure, Local
CGL = + 57567.5 + 0.0595819*XGL + 0.77758*CGL(-1)
    Sa|ple 1976-1989 (RRADJ=0.99440 S.E.=9230.26 D.N. = = . % 223
```

4. Government Final Consumption Expenditure, Municipal
$C \dot{G} M=-2377 \mathrm{E}+03+0.92863 * T Y M G+0.45982 * P 0 \mathrm{P}$
Sanple $1976-1989 \quad$ RRAD $J=0.98960 \quad$ S. $\mathrm{E} .=16540.20 \quad$ D.H. $=1.169$
5. Government Pinal Consumption Expenditure
$\dot{C} \dot{G}=C G C+C G L+C G H$
6. Private Non-residential Investment
$I P C=R I P C * P I P C / 100$
7. Private Residential Investment
$I P H=R I P H * P I P H / 100$
8. Public Fixed Investrent
$\operatorname{LOG}(I G)=+2.71395+0.38248 * \operatorname{LOG}(X G C D+X G C D(-1))+0.51250 *(X G L A A L)$
Sapple 1976-1989 ${ }^{4}$ ) 2.85 ) S.E. $=0.04$ D.H. $=1.357^{3.15)}$
9. Increase in Stocks, Private
$j \dot{P}=\operatorname{RIIP} * \mathrm{PIPC} / 100$
10. Increase in Stocks, Goverament
IG $=$ RIIG*PIGC/100
11. Export of Goods and Services
E = RE*PE/100
12. Inport of Goods and Services
$M=R M * P M / 100$
13. Gross Donestic Expenditure of Hokkaido, Nominal Term
$G D \dot{E}=C P+C G+I P C+I P H+I G+J P+J G+E-M+S D$
14. Banks Loans for Private Housing
DSLBHP $=-2287.65+88.4350 * I R C+0.0044119 * I P H(-1)$
Sample $1976-1989$ RRADJ $=0.89692$ S.E. $=164.38$ D.H. $=1.894$
G. INCOME AND TAX SECTOR
15. Hage per Employ
$\operatorname{LOG}(H)=+5.24137+1.25428 * \operatorname{LOG}(J C P I)+0.541151 * \operatorname{LOG}($ RGDEC $)$
$+\left(\begin{array}{c}0.52) \\ -1.2599 * L O G(L N) \\ -1.53)\end{array}\right)$
$-1.51)$
4.83)
Sample 1976-1989 BRADJ=0.99208 S.E. $=0.02$ D.W. $=1.857$
16. Nage Index of Regular Norkers
$\mathrm{I}=\mathrm{h} / 3.13338 * 100$
17. Wage Incone of Employees
$Y H=P * L W N$
```
4. Contribution to Social Insurance, Household
```


5 Property Incone of Household, Interest

Saple 1976-1989 RRADJ=0.98553 S.E. $=27167.60$ D. $\begin{gathered}8.26) \\ =1.509\end{gathered}$
6. Property Income of Household, Dividend

Sanple 1976-1989 RRADJ=0.96317 S.E. $=10723.60 \quad$ D. W. $=2.549$
7. Property Income of Household, Rent

Sample 1976-1989 RRADJ $=0.96519$ S.E. $=1988.77$ D.W. $=2.935$
8 . Property Incone of Household
YAH $=$ YAHI + YAHD + YAHR
9. Proprietor's Income, Agriculture, Forestry and Fisheries
$\mathrm{YCIA}=+386657+0.76826 *(0 \mathrm{~A}+0 \mathrm{~F})-6963.0 * \mathrm{PM}$
$+\begin{gathered}1.68)(2.76) \\ +(68660 * W \\ -2.04)\end{gathered}+0.24642 *$ YCIA $(-1)(-4.33)$
Sample 1976-i989 RRADJ=0.70354 S.E. $=41275.60 \quad$ D.H. $=2.201$
10 Proprietor's Income, Trade and Industries
$\operatorname{LOG}(Y C I I)=+18.7908+2.90818 * \operatorname{LOG}(G D E)-4.12934 * \operatorname{LOG}(Y W(-1))$

Sample 1976-1989 RRADJ $=0.88838$ S.E. $=0.09$ D.W. $=2.644$
11. Proprietor's Incone, Rent and Lease
 $+\begin{gathered}3.56) \\ +2.0584 * L O G(C P I) \\ 2.29)\end{gathered}$
Sample 1976-1989 RRADJ=0.95717 S.E. $=0.09$ D.H. $=1.567$
12. Proprietor's Income

YCI = YCIA + YCII + YCIR
13. Household Income
$Y P=Y W-X H W+Y A H+Y C I$
14. Household Disposal Income

YD $=$ YP - TYM - TYCI - TYLG - TYMG - TAM
15. Number of Automobile

$+0.72452 * \operatorname{LOG}(A M N(-1))$
(18.57)

Sanple $1976-1989$ RRADJ $=0.99858$ S.E. $=0.01$ D.W. $=1.600$
16. Personal Income Tax
$T Y W=-75975.5+0.0658690 * Y H$
Saゅple 1976-1989 RRADJ=0.90050 S.E. $=28770.00$ D.H. $=0.414$
17. Tax on Private Business

Sample 1976-1989 RRADJ $=0.92813$ S.E. $=6843.69 \quad$ D.H. $=1.090$
18. Residents' Tax, Local

TYLG $=-\underset{(18474.2}{ }-5.58)+0.0660613 * V G L$
Sample 1976-1989 RRADJ $=0.98891$ S.E. $=2925.99$ D.H. $=1.547$
19. Residents' Tax, Municipal

anple 1976-1089 RRADJ=0.99847 S.E. $=0.01$ D.R. $=2.041$
20. Tax on Autonobile Holding

21. Corporate Income
$Y C P=+\begin{aligned} & 1210 E+03 \\ & 4.36)\end{aligned}+0.34011 * G D E-33791.4 * I R P-1424 E+03 * 甘$

22. Corporate Direct Tax

L0G $($ TYCP $)=-13.9201+0.76303 * L 0 G(Y C P)+1.10465 * \operatorname{LOG}(R I P C(-1))$

23. Domestic Consumption

LOG $(C P D)=+\begin{aligned} & 1.80463 \\ & 3.65)\end{aligned}+(.87167 * L 0 G(C P)$
Sa』ple $1976-1989$ RBADJ $=0.98343 \quad$ S.E. $=0.03 \quad$ D.H. $=2.760$

APPENDIX B: Table 1 Baseline Projection
Table 2 Scenario A
Table 3 Scenario B



|  | Impactsoo |  | $¥ 43$ | t r | 1 i 0 n | CSec | nati | A) | Jap | anese | econ |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| macro | 1998 | 1991 | 1892 | 1993 | (differences) |  |  |  | 1998 | 1989 | 2080 |
| GDE | 8 | 8 | 8 | 11393 | 33411 | 63683 | 99836 | 148378 | 195329 | 234081 | 286286 |
|  | 0 | a | 0 | 0.07 | B. 2 | 0. 37 | 0. 56 | 0.77 | 6.98 | 1.23 | 1.47 |
| CP | 0 | 0 | 0 | 882 | 4538 | 11743 | 23019 | 38293 | 57429 | 80218 | 188409 |
|  | 0 | 0 | 0 | 0.01 | 0.04 | 0.11 | 8.2 | 8. 33 | 6. 18 | 0.68 | 0.85 |
| IPH | 0 | 0 | 0 | 2269 | 8623 | 17524 | 27794 | 37797 | 47598 | 58855 | 65510 |
|  | 0 | 8 | 0 | 0.27 | 1.83 | 2.69 | 3.28 | 4.41 | 5.17 | 8.44 | 7.3 |
| IPC | 0 | 0 | 0 | 2762 | 7438 | 13403 | 20502 | 28383 | 36811 | 45979 | 55753 |
|  | 0 | 0 | 0 | 0. 11 | 0.29 | 0. 5 | 0.75 | 1.02 | 1.3 | 1.58 | 1.89 |
| CO | 0 | 0 | 0 | -462 | -1492 | -3006 | -5088 | -7467 | -10873 | -12827 | -15646 |
|  | 0 | 0 | 0 | -0.82 | -0.07 | -0.14 | -0.24 | -0.34 | -0. 45 | -0.57 | -0.69 |
| 216 | 0 | 0 | 0 | 4104 | 14467 | 27852 | 43416 | 68417 | 78667 | 98072 | 118435 |
|  | - | 0 | 0 | 0.2 | 0.69 | 1.28 | 1.91 | 2.56 | 3.22 | 3.87 | 4.54 |
| E | 0 | 8 | 8 | 5715 | 11320 | 17453 | 23999 | 38787 | 37844 | 15174 | 52744 |
|  | 8 | 0 | - | 0. 11 | 0. 22 | 0.34 | 0. 45 | 0. 58 | 0.7 | 0. 82 | 0. 95 |
| 14 | © | 0 | 0 | 3876 | 11482 | 21386 | 34011 | 47761 | 62938 | 79410 | 97005 |
|  | 0 | - | 0 | 0.85 | 0. 15 | 0.27 | 0. 43 | 0.59 | e. 76 | 0.94 | 1.13 |
| GDE | © | 0 | 0 | 0.02 | 0. 06 | 0. 11 | 0.18 | 0. 26 | 0. 35 | 0. 45 | 0.55 |
|  | 0 | 0 | 0 | 0. 82 | 0. 05 | D. 1 | 0.16 | 0. 22 | 0.3 | 0. 38 | 0. 46 |
| 1 | 0 | $\bigcirc$ | 0 | 0.02 | -. 06 | 0.12 | 0.2 | 0. 28 | 0. 38 | 0. 47 | 0.58 |
|  | 0 | 0 | 0 | 0.02 | 0.06 | 0.11 | 0. 18 | 0.26 | 0. 35 | 0. 44 | 2.53 |
|  | 0 | 0 | 8 | 0.00045 | 0.08183 | 0.00434 | 0. 88739 | 0.0114 | 0.01683 | 0. 82119 | -. 02689 |
|  | 0 | 0 | 0 | 0.01 | 0.85 | 0. 11 | 0. 19 | 0. 29 | 0. 4 | 6.53 | 0. 65 |
| N | © | 0 | 0 | 368 | 1098 | 2060 | 3299 | 4633 | 6056 | 7537 | 9038 |
|  | 0 | 0 | 8 | 0.01 | 0.84 | 0.87 | 0.11 | 0. 16 | 0.2 | 0.25 | 0.3 |
| ENN | 0 | 0 | 0 | 531 | 1548 | 2802 | 4345 | 5952 | 7614 | 9313 | 11027 |
|  | 0 | 0 | 0 | 0.02 | 0.85 | 6. 1 | 0.15 | 0. 21 | 0.26 | 0. 32 | 0.38 |
| WN | 0 | 0 | 0 | 456 | 1527 | 3188 | 5188 | 7548 | 10126 | 12867 | 15723 |
|  | 0 | 0 | 0 | 0.82 | 0:06 | 0. 12 | 0.2 | 0. 29 | 0.39 | 0. 49 | 0.6 |
| DH | 0 | 0 | 0 | 0. 00277 | 0.08573 | D. 08857 | 0.011 | 0.01325 | 0. 01533 | 0. 01739 | 0. 8195 |
|  | 0 | 0 | 0 | 0. 35 | 0.67 | 0.94 | 1.14 | 1.31 | 1.45 | 1.57 | 1.69 |
| Op | 0 | 0 | 0 | 120 | 383 | 724 | 1177 | 1634 | 2846 | 2369 | 2563 |
|  | 0 | 0 | 0 | 0 | 0.01 | 0.01 | 0.02 | 6. 03 | 0.04 | 0. 04 | 0.85 |
| 0-10) | 1990 | 1991 | 1992 | 1983 | 1994 | 1895 | 1996 | 1997 | 1998 | 1899 | 2089 |
| Sum | 0 | 0 | - | 27732 | 81520 | 155516 | 246824 | 358556 | 468672 | 591404 | 733992 |
|  | 0 | 0 | B | 0.08 | 0. 23 | 0. 42 | 0. 65 | 0.91 | 1.17 | 1.45 | 1.74 |
| PR | 0 | 0 | 8 | 2422 | 5635 | 9743 | 14722 | 20356 | 26651 | 33582 | 41155 |
|  | 0 | 0 | e | 0.09 | 0. 2 | 0. 35 | 0.51 | 0.69 | 0.89 | 1.09 | 1.31 |
| Sc | $\square$ | 0 | 0 | 16850 | 50433 | 95276 | 148665 | 207198 | 270926 | 339381 | 412734 |
|  | 0 | 0 | $\theta$ | 8. 12 | 0. 36 | 0.66 | 1.81 | 1.37 | 1.74 | 2.12 | 2.51 |
| TR | 0 | 0 | 0 | 8460 | 25454 | 58498 | 83430 | 123006 | 169894 | 221442 | 280092 |
|  | 0 | 0 | - | 0.85 | 0. 13 | 0. 26 | 0. 42 | 0.6 | B. 8 | 1.01 | 1.24 |




Fields of Influence of Technological Change in EC Intercountry Input-Output Tables, 1970-80
by Jan A. van der Linden, Jan Oosterhaven, Frederico A. Cuello, Geoffrey J.D. Hewings and Michael Sonis

# Fields of Influence of Technological Change in EC Intercountry Input- 

## Output Tables, 1970-80

Jan A. van der Linden ${ }^{1}$, Jan Oosterhaven ${ }^{1}$, Federico A. Cuello ${ }^{2}$,<br>Geoffrey J.D. Hewings ${ }^{2}$, and Michael Sonis ${ }^{2}$


#### Abstract

Technological change does not only have an impact on the sectors and countries in which it occurs. It also influences the functioning of the economy at large. An efficient and integrated way to summarize the impact on the interdependence of sectors and countries is by looking at an intercountry Leontief-inverse.

In this paper we will investigate the influence of changes in the technical coefficients in one sector in one country on the intercountry Leontief-inverse of the European Community (EC) for 1970 and 1980, estimated by Boomsma, van der Linden and Oosterhaven (1991). This will be done with a weighted variant of the Field of Influence of Column Change as developed by Sonis and Hewings (1992). The empirical outcomes will be analyzed in three ways.

First, we will analyze the impact of comparable changes in technology in every sector on the aggregate value of the Leontief-inverse as well as on its spatial structure. In this way 'propulsive' sectors are identified as those sectors that produce the largest increase in the overall interdependence between all sectors in all EC-countries. Moreover, the propulsiveness of sectors, thus measured, will be spatially decomposed into a 'domestic' effect, an 'intercountry-spillover', an 'intercountry-return' and a 'rest of the EC' effect on sectoral interdependence.

Secondly, we will analyze how the columns of the intercountry Leontief inverse change as a consequence of EC-wide changes in technology. Thus we identify 'reactive' sectors as those sectors whose multipliers are most sensitive to EC-wide factor productivity increases. Thirdly, we analyze how the rows of the intercountry Leontief-inverse change as a consequence of EC-wide changes in factor productivity. This approach identifies 'dependent' sectors as those sectors whose production level is most sensitive to overall changes in productivity within the EC.

At each level of the analysis, attention will be given to the temporal changes in propulsiveness, reactiveness and dependence of sectors and countries within the EC over the period 1970-80.


[^5]
## 1. Introduction

Innovations and technological change are known to spread over time and over space. In the input-output literature, Carter's (1970) pioneering study provided a useful methodological approach to the issue of system-wide aggregate change. In addition, extensive models of innovation diffusion have been developed to this date (see e.g. Davies, 1979; Nijkamp, 1986). Most of these theories, however, concentrate upon the diffusion process of one type of innovation at a time. Some studies deal with the simultaneous diffusion process of independent but mutually competing innovations, each maybe having its own specific niche and maximal penetration (see e.g. Sonis, 1992). As far as interdependent innovations are concerned one finds some attention to the spillover of key-innovations in one area (e.g. microprocessors) unto the technologies used in other areas (e.g. consumer electronics). These latter theories, e.g., concentrate on the phenomenon of technological trajectories (Dosi, 1984). However, we have not found studies of the system-wide implications of changes in technology, nor comparative studies into the system-wide implications of series of different new technologies, although Grossman and Helpman (1991) have attempted to explore the basis for an approach to this problem.

In this paper we will set a prudent first step to fill this gap. Of all system-wide implications of new technologies we will deal only with one major, but specific, effect of new technologies, namely their impact on the interdependence of an economic system. In this context, interdependence has two important aspects which we would like to investigate simultaneously. First, technological change influences of course the way in which sectors interact with one another through the exchange of products. Second, we would like to investigate the extent to which this influence spills over into other countries. In this last context we are interested in the question whether this intercountry spillover of technological change increases over time or not, especially, when countries integrate their economies such as is done in the European Community (EC).

The ideal data base to investigate the above questions consists of course of a time series of intercountry input-output tables which allows us to study the intersectoral interaction both within and between countries over time. Recently such tables have been constructed for the EC for 1970 and 1980. The peculiarities of their construction are discussed briefly in the next section (see Boomsma et al, 1991, for details).

The effect of technological change on the interdependency of sectors, within and between countries, is best measured by the effects of changes in a column of technical coefficients on the values of the intercountry Leontief-inverse $(I-A)^{-l}$. Section 3 explains the method used to calculate these effects, namely a weighted variant of the Fields of Influence of Column Change (see Sonis \& Hewings, 1992, for details on other Fields of Influence).

Sections 4-6 then give a three-way summary description of the empirical results that consist of 5(countries) x 6(industries) Fields of Influence with each 30 rows and columns for 1970, and $7 \times 6$ Fields with 42 rows and columns for 1980. In Section 4 we analyze the impact of a comparable change in factor productivity in every sector in each EC-country on the aggregate value of the intercountry Leontief-inverse as well as on its aggregate spatial structure. Thus we identify so-called propulsive sectors studied earlier for Brazil by Cuello et al. (1992). Next, in Section 5, we analyze which production multipliers are most sensitive to EC-wide factor productivity increases in order to identify so-called reactive sectors (cf. also Cuello et al., 1992). Finally, in Section 6, we extend the analyses of Cuello et al., and we analyze how the rows of the intercountry Leontiefinverse change as a consequence of EC-wide changes in factor productivity. Thus, dependent sectors and countries are identified as those whose production levels are most sensitive to overall changes in factor productivity within the EC.

At each level of analysis, attention will of course be given to the temporal changes in propulsiveness, reactiveness and dependence of sectors and countries within the EC over the period 1970-80.

## 2. EC Intercountry Input-Output Tables

The data used in examining the fields of influence of technological change in the European Community are intercountry input-output tables for 1970 and 1980. These tables are constructed from a set of mutually harmonized national input-output tables (see Eurostat, 1979, for the methodology). In these harmonized tables, domestic transactions are valued in producers' prices, and imports in ex-customs prices. Furthermore, the imports are distinguished according to two origins, namely imports from within the EC and imports from outside the EC. Such tables are issued every five years (see for 1970 and 1980: Eurostat, 1978; 1986), but they are not available for all
member states. For both years there are no tables for Luxembourg, and for 1980 the table for Ireland is lacking too. So, the data suitable for analysis relate to five and seven countries for 1970 and 1980, respectively.

To obtain the intercountry tables, the respective (five or seven) tables with intraEC imports were first disaggregated into one table with the bilateral, intersectoral transactions between all pairs of EC-countries. International trade data were used to do this. Second, to reassess the ex-customs valuation of the intra-EC imports into producers' prices, the RAS method was applied to that bilateral transactions table. Details of the construction method are given in Boomsma et al. (1991). For earlier constructions and applications of EC intercountry input-output tables, see Schilderinck (1984), Langer (1987), Lanza and Rampa (1988), Oosterhaven (1989b) and Fehr et al (1991). In all these tables, however, ex-customs prices were not reassessed.

The original intercountry tables of Boomsma et al (1991) have 44 sectors. For our analysis, we have aggregated them into 6 sectors, namely Agriculture, Energy, Manufacturing, Building, Market Services and Public Services.

## 3. Fields of Influence of technological change

The notion of Fields of Influence was originally developed to guide the construction and estimation of regional input-output tables. As such, it focused on error and sensitivity analysis and the identification of inverse-important coefficients (Sonis and Hewings, 1989). Later on, the approach also proved to be useful for the analysis of the structure of input-output tables and the identification of key sectors (Cuello et al, 1992; Sonis and Hewings, 1992).

### 3.1. The Notion of Fields of Influence

The basic formula of the impact of a change $e_{m c}$ in one input coefficient on the whole Leontief-inverse is:

$$
\begin{equation*}
B(E)=B+\frac{1}{1-b_{c h} e_{h c}} F\binom{c}{h} e_{h c}, \tag{1}
\end{equation*}
$$

where $B$ and $B(E)$ are the Leontief-inverses before and after the change, and where $F$ is the Field of Influence:

$$
\boldsymbol{F}\binom{c}{h}=\left(\begin{array}{c}
b_{1 k}  \tag{2}\\
b_{2 k} \\
\cdot \\
\cdot \\
b_{n k}
\end{array}\right)\left(b_{c c}, b_{c 2}, \ldots, b_{c k}\right)
$$

The typical element of $B(E)$ is calculated as:

$$
\begin{equation*}
b_{i j}(E)=b_{i j}+\frac{b_{c j} b_{i h} e_{h c}}{1-b_{c h} e_{h c}}, \tag{3}
\end{equation*}
$$

which is the well-known Sherman and Morrison (1950) formula of inverse change.
In order to analyze the sensitivity of the Leontief-inverse to the technological change in one sector we need to consider possible sets of changes in one column $c$ :

$$
\begin{equation*}
e^{c}=\left(e_{1 c}, e_{2 c}, \ldots, e_{n c}\right) \tag{4}
\end{equation*}
$$

In this case, the extension of equation (3) is (see Sherman and Morrison, 1949):

$$
\begin{equation*}
b_{i j}(E)=b_{i j}+\frac{b_{c j} \sum_{k} b_{i h} e_{h c}}{1-\sum_{h} b_{c k} e_{h c}} \tag{5}
\end{equation*}
$$

One can make many alternative assumptions about the structure of the changes in (4). The most obvious one is an equal relative increase in all coefficients. Such a change is the typical result of an increase in primary input (e.g. capital or labour) productivity, under the assumption of an unchanged mix of intermediate inputs. This case is specified as:

$$
\begin{equation*}
e_{i c}=\alpha a_{i c} . \tag{6}
\end{equation*}
$$

Other obvious assumptions are, for example, a substitution between two specific intermediate inputs $h_{0}$ and $h_{o}^{\prime}$ :

$$
e_{h_{f f}}=-e_{h h_{f}},
$$

or a more efficient use of one specific intermediate input:

$$
e_{h_{f} f}=\alpha a_{h_{f}}, \quad \text { and for } h_{t} \neq h_{0}: \quad e_{h_{f}}=-\frac{e_{h_{f}} a_{h f}}{\sum_{h_{i} h_{0}} a_{h_{f}}} .
$$

In all cases the mix of other intermediate and primary input coefficients remains unchanged. These alternatives represent some basic cases of column change.

In this paper, we will only analyze the implications of the first alternative. This alternative is analytically most tractable and thus convenient as a first step in the analysis. It may also prove to be the most general and empirically reasonable assumption. Substitution of (6) into (5) then results in:

$$
\begin{equation*}
b_{i j}(E)=b_{i j}+\frac{\alpha b_{c j} \sum_{h} b_{i h} a_{h c}}{1-\alpha \sum_{h} b_{c h} a_{h c}} \tag{7}
\end{equation*}
$$

To obtain the structure of the impact of $\alpha$ on the Leontief-inverse, we only need to investigate the linear part of the change:

$$
\begin{equation*}
f_{i j}^{c}=b_{c j} \sum_{h} b_{i h} a_{h c}, \tag{8}
\end{equation*}
$$

where the matrix $F^{c}=\left\|f_{j}^{c}\right\|$ is called the Weighted Field of Influence of Column Change or the Column Field of Influence. It is defined in (8) as the weighted sum of the Fields of Influence of column $c$ (see Sonis and Hewings, 1992, for the unweighted version).

The structure of our weighted column field of influence, $F$, can be analyzed with the help of the matrix $G=B A=(B-I)=\left\|s_{i j}\right\|$, which is the matrix of indirect production effects; in coordinate form:

$$
\left\{\begin{array}{l}
g_{i j}=b_{i j}, \quad i \neq j \\
g_{i i}=b_{i i}-1
\end{array}\right\}
$$

Using $G$, the components $f_{i j}^{c}$ can be presented in a form where the elements $a_{i j}$ are excluded:

$$
\begin{align*}
& f_{i j}^{c}=b_{c j} g_{i c} \\
& \text { or } \\
& \left\{\begin{array}{lr}
f_{i j}^{c}=b_{c j} b_{i c}, & i \neq c \\
f_{c j}^{c}=b_{c j}\left(b_{c c}-1\right)=b_{c j} b_{c c}-b_{c j}
\end{array}\right\} .
\end{align*}
$$

The components $b_{c} b_{i c}$ are the components of the field of influence, $\boldsymbol{F}\binom{c}{c}$, of the change occurring in the place ( $c, c$ ). Therefore, the weighted column field of influence has the form:

$$
F=F\binom{c}{c}+\left(\begin{array}{ll}
\text { Row } & c
\end{array}\right),
$$

where the matrix

$$
\left(\begin{array}{lll}
\text { Row } c
\end{array}\right)=\left(\begin{array}{cccc}
0 & 0 & . . & 0 \\
: & : & . . & : \\
0 & 0 & . . & 0 \\
b_{c 1} & b_{c 2} & . & b_{c n} \\
0 & 0 & . . & 0 \\
: & : & . . & : \\
0 & 0 & . & 0
\end{array}\right)
$$

includes only row $c$ from the matrix $B$.
From (8'), it is clear that a Column Field of Influence depends on backward linkages. The impact on the individual multiplier $b_{i j}$ will be stronger, (1) the stronger $j$ 's total backward linkage with respect to $c$, the sector with the factor productivity increase, and (2) the stronger $c$ 's indirect backward linkages with respect to $i$. Per column $j$ the impacts are larger when $j$ has strong backward linkages with $c$. Per row $i$ the fields have high loadings when the direct backward linkages of $c$, with regard to $i$, are strong. Hence, strong backward linkages, both of and with respect to a certain sector, cause that sectors' technological changes to have a strong impact on the Leontief-inverse. This means that productivity increases in key sectors, as defined in the traditional sense (see Dietzenbacher, 1991), will have an especially strong impact on the Leontief-inverse too.

For comparisons between sectors, $c=1,2, \ldots, n$, we basically cannot restrict ourselves to these Column Fields of Influence (8), as the ranking of sectors is dependent on a scaling factor, namely on the denominator of (7). However, when $\alpha$ is sufficiently small, the ranking will not be influenced by that scaling factor, and (8) can be used for
comparative purposes too. This can be proven by taking the derivative of (7) with respect to $\alpha$ (see also Sonis and Hewings, 1992).

The Column Fields of Influence can now be represented by a three-dimensional block, with $i$ and $j$ as the horizontal and vertical dimensions and $c$ as the 'depth' dimension (representing the causes of change in $i$ and $j$ ). In the next three sections, we will analyze the above defined interindustry and intercountry Column Fields of Influence of the EC. These analyses will be made by means of summary measures of the two blocks of $n$ matrices (i.e. 30 or 42) for 1970 and 1980, respectively. Each time, elements of the basic interpretation of the Fields of Influence given above will return. The remainder of this section explains the methodology chosen.

### 3.2. Methodology of the empirical analysis

Most straightforward is the analysis of the impact of comparable sectoral productivity increases on the aggregate value of the Leontief-inverse. In this way propulsive sectors are identified as those sectors that produce a relatively large increase in the overall interdependence between all sectors of all EC-countries (Cuello et al., 1992).

As we are dealing with an intercountry system, we need to introduce additional indices to indicate the countries of origin and destination. For convenience, however, we introduce the indices $p$ and $q$ as the combined index for country and sector. Thus, propulsiveness is defined as the total of the effects on the Leontief-inverse, i.e. as the Volume of Column Field of Influence:

$$
\begin{align*}
& V^{c}=\sum_{p q} b_{c q} g_{p c}=\sum_{p q} b_{c q} b_{p c}-\sum_{q} b_{c q}=b^{c} b_{c}-b_{c}, \\
& \text { with } b^{c}=\sum_{p} b_{p c} \text {, and } b_{c}=\sum_{q} b_{c q} . \\
& \text { Denote } \lambda_{c}=b^{c}-1 \text {, then } V_{c}=\lambda_{c} b_{c} . \tag{9}
\end{align*}
$$

This Volume is equal to the sum of row $c$ times the sum of column $c$ of the Leontiefinverse, the latter without the direct effect. Hence, the total impact of a productivity increase in sector $c$ depends on its own backward linkages, and on changes in the rest of the system interpreted through the field of influence (see Section 4.1 for the results).

There are many ways to analyze the structure of an individual Field of Influence further. They range from a detailed element by element approach to a global approach,
building on broad aggregations of the matrix. For our present purposes we will confine ourselves to the latter.

To see whether the individual Fields have a largely domestic character or also have significant intercountry elements, let $P^{c}$ be defined as:

$$
\begin{align*}
& \boldsymbol{P}^{c}=\left\|p_{p q}^{c}\right\| \\
& \text { where } p_{p q}^{c}=\frac{100 f_{p q}^{c}}{V^{c}}, \quad \quad p, q=1,2, \ldots, n . \tag{10}
\end{align*}
$$

This expresses the elements of the Field of Influence of column $c$ as a percentage of the sum of that matrix. Its aggregate spatial structure is now obtained by summing $P^{c}$ into four components:

$$
\begin{array}{ll}
P_{c c}^{c}=\sum_{\substack{p \in C \\
q \in C}} p_{p q}^{c} & P_{c s}^{c}=\sum_{\substack{p \in C \\
q \in s \sim C}} p_{p q}^{c} \\
P_{r c}^{c}=\sum_{\substack{p \in r \cdot c \\
q \in C}} p_{p q}^{c} & P_{r s}^{c}=\sum_{\substack{p \in r+c \\
q \in s \in C}} p_{p q}^{c}, \tag{11}
\end{array}
$$

where $r$ and $s$ denote the countries of origin and destination, and where $C$ is the country in which industry $c$ is located.

In this decomposition:
$P_{c c}^{c}$ represents the percentage of the total effect on the Leontief-inverse that is located in its block diagonal domestic part. It consists of pure domestic and intercountry feedback effects. The latter, however, are more or less negligible (cf. e.g. Oosterhaven, 1981; Miller, 1986). Hence, the domestic part gives an indication of the closed nature of an economy to the effects of its productivity changes.
$P_{r c}^{c}$ is the intercountry-spillover effect induced by imports from the rest of the EC. It will be large if country $C$ has a large share of intra-EC imports, i.e. strong intercountry backward linkages. Foreign industries will thus be influenced by technological developments in country $C$.
$P_{c s}^{c}$ is called the intercountry-retum effect induced by exports to the rest of the EC. Its value will be large when country $C$ s products are important for other EC-
countries.
$P_{r s}^{c}$, finally, is the sum of all the multiplier effects that are not related to country $C$. Hence, it is labeled as the rest of the EC effect. Its value will vary with country $C$ 's openness as regards its intra-EC imports and its intra-EC exports.

Of these four components, the first is expected to be the largest. Despite the growing economic integration of the EC, the strongest linkages are still domestic. The intercountry components are expected to be smaller, although they may grow in importance (c.f. Oosterhaven, 1989b). In the fourth part, the effects of the intercountry components are combined. Therefore, the rest of the EC component is expected to be very small (see Section 4.2 for the results).

The two other types of aggregations of the block with Column Fields of Influence are less straightforward as they go into more detail, but at the same time also involve an aggregation over the individual Column Fields of Influence. They are set up to compare, respectively, the sensitivity per column and per row of the Leontief-inverse.

In Section 5 we analyze which production multipliers are sensitive to EC-wide changes in technology. Thus we identify reactive sectors as those sectors (and countries) whose multipliers are most sensitive to comparable factor productivity increases in all sectors and countries of the EC. For each individual $c$, we can identify reactive sectors, $q$, by ranking $\Sigma_{p} f_{p q}^{c}, q=1,2, \ldots, n$. Each $c$, however, will give a different ranking, with $c$ itself as the most reactive sector ${ }^{3}$. Hence, the general set of reactive sectors cannot be derived unambiguously. For the moment we will assign all sectors an equal weight, i.e., we assume that all sectors have an equal chance to meet a productivity change. So we identify 'average' reactive sectors by summing $\Sigma_{p} f_{p q}^{c}$ over $c$ :

$$
\begin{align*}
S_{q} & =\sum_{p c} b_{c q} g_{p c}=\sum_{c}\left[\sum_{p+c} b_{c q} b_{p c}+b_{c q}\left(b_{c c}-1\right)\right]  \tag{12}\\
& =\sum_{c}\left[b_{c q} b^{c}-b_{c q}\right]=\sum_{c} \lambda_{c} b_{c q},
\end{align*}
$$

$$
q=1,2, \ldots, n
$$

This is the column multiplier of sector $q$ itself, but weighted with the indirect backward

[^6]linkages of $c$ as in (9). The reactiveness of a sector is thus strongly dependent on its backward linkages. When it is a key sector, it reinforces its position especially when there is a strong relation with other key sectors.

Although this analysis looks along the columns of the intercountry Fields of Influence, the results should not be confused with measures of backward linkages. The relation actually runs the other way round. It is the impact of changes in technologies transmitted through backward linkages that is measured, and not the backward linkages themselves.

In Section 6 we analyze how the rows of the intercountry Leontief-inverse change as a consequence of comparable changes in factor productivity in all sectors in all countries. Here it would be wrong to associate the results with measures of forward linkages simply because the Fields of Influence are analyzed row-wise instead of columnwise ${ }^{4}$. To the contrary, this way of analysis identifies what may be called dependent sectors. These are sectors and countries whose production levels (through backward linkages of other sectors) are most sensitive to overall changes in factor productivity within the EC.

Like the previous case, we again have the problem of ambiguity, which is now even stronger. Not only for each $c$, but also for each $q$ we can derive an alternative ranking of sectors. Again we assume that all sectors have an equal factor productivity increase. we now also assume that (implicit) changes in demand for commodities from sector $q$ are equally important ${ }^{s}$. Hence, we now sum $f_{p q}^{c}$ over $c$ and $q$ :

$$
\begin{equation*}
S_{p}=\sum_{c q} b_{c q} g_{p c}=\sum_{c=p} b_{c} b_{p c}+b_{p}\left(b_{p p}-1\right), \quad p=1,2, \ldots, n . \tag{13}
\end{equation*}
$$

In (13), strong backward linkages with respect to $p$ make its production highly sensitive to technological changes elsewhere in the economy.

## 4. Analysis of Propulsive Sectors

[^7]In this section we will concentrate on a comparison of the separate Column Fields of Influence by looking at the aggregate size and spatial structure of changes in the Leontief-inverse that are due to a small factor productivity increase in each column $c$. First, we will analyze the Volumes of the Fields as calculated from (9). Secondly, we will look at the spatial structure of the Fields by means of the intercountry decomposition of the Volumes given in (11).

### 4.1. The Volume of Column Fields of Influence

The EC-wide Volumes of Fields of Influence in 1970 and 1980 are given in Table 1 and are illustrated in Figures 1 and 2. The Volumes are arranged in a two-dimensional (country by sector) way. This shows not only which sectors' productivity changes would have the strongest impact upon the Leontief-inverse, but also which member states would exert the greatest influence. The criterion for the arrangements is the average Volume of Column Field of Influence per sector and country, respectively. In both parts of Table 1, the propulsiveness declines from the upper left to the lower corner. In Figures 1 and 2, this is shown graphically.

Both from Table 1 and Figure 1, we observe that for 1970, German Manufacturing would have the strongest impact on the Leontief-inverse, followed by Manufacturing in France, The Netherlands, Italy and Belgium, respectively. Then, we find, respectively, Agriculture, Market Services and Building, with only small mutual differences between their impacts. There one finds some exceptions to the general order of the member states. French and Italian Agriculture, Belgian Market Services, and French and German Building would have relatively weak impacts. The weakest influences would be exerted by Energy and Public Services in all member states. Here, only German Energy, which is more strongly based on (domestic) coal, is a positive exception.

To understand the pattern of Figure 1, one has to remember that the impact of productivity changes in sector $c$ primarily depends on its own indirect backward linkages and on the total backward linkages of the other sectors with respect to $c$. In 1970, Manufacturing had the strongest linkages of both types in all five countries. This would explain its dominance upon the Leontief-inverse. This linkage strength itself, however, is largely dependent on the relative size of the sector. A lower level of aggregation would
reveal a more varied pattern of potential impacts.
In Agriculture and Building, both the column and the row elements of the Leontief inverse are close to the average, which explains their middle position in the ranking of propulsive sectors. Market Services and Energy have relatively weak backward linkages since they use little material inputs (roughly about $30 \%$ ). However, this is compensated by the strong use of their products by other sectors. Of these two sectors, Market Services strongly depend on labour, whereas Energy uses significant oil imports from outside the EC. Finally, Public Services have very weak linkages, which explains the small potential impact of productivity changes in this sector.

Just as with the sectoral order, economic size explains part of the country order in Figure 1. For the other part, the country order is explained by each country's openness with respect to the other EC-countries. The larger openness of the Benelux countries explains why the propulsiveness of their sectors in 1970 ranks between those of two larger countries, France and Italy.

In 1980 (see Table 1 and Figure 2) the pattern essentially remains unaltered. The order of sectors is still the same. Even the exceptions remain the same. This suggests the presence of a strong structural component in the relationships between most sectors. Only the Dutch Building sector, having a much stronger potential impact in 1980, may be added to the exceptions. Contrary to the order of sectors, the order of countries did change, but not in a dramatic way. Italy 'climbed' to a mid-position (due to increases in the linkages of its Manufacturing and Market Services), but the differences with France, The Netherlands and Belgium are still small.

Of the two new member states, Denmark fits well between the other two small economies. Only its Energy productivity changes would have a surprisingly strong impact on EC interdependence. The strong position of the United Kingdom, on the other hand, was surprising. For four sectors, Agriculture, Building, Energy and Public Services, its productivity changes would have the largest impact on the intercountry Leontief-inverse. For the other two sectors, the impacts would only be slightly weaker than the German ones. The British impacts, however, would be largely domestic, as will be shown below.

### 4.2. The Spatial Structure of Column Fields of Influence

Next, we turn to the spatial structure of the individual Column Fields of Influence. The
hypothesis about the relative size of the components of (11), as formulated in Section 3.2, is confirmed by the empirical outcomes shown in Table 2. In 1980, the domestic component generally ranges between 70 and $90 \%$ of the Volume of the individual Fields, the intercountry-spillover effect ranges between 10 and $30 \%$, and the other two components hardly exceed $10 \%$ and $2 \%$, respectivelys.

Although this spatial structure of the individual Fields appears to be quite general, Table 2 also shows some interesting differences among sectors and member states. In 1980, Agriculture, Building and both Service sectors would have much stronger domestic effects than Energy and Manufacturing. This is caused by the traditionally high openness for fuel and manufacturing products. The openness to agricultural products and services is lower. In 1970, the pattern is the same except for Energy which showed much larger domestic impacts than in 1980.

As could be expected, the small countries' openness is reflected in their relatively small domestic and large intercountry effects, while the closed nature of the large member states is reflected in large domestic and small intercountry effects. Here we indeed find that the strong overall multiplier effects of the United Kingdom are largely domestic. This implies that the rest of the EC would feel little influence of UK productivity changes. Italy too seems to be quite closed but more so in 1970 than in 1980. Of the three small economies, the Danish is most closed. Remember, however, that we are only evaluating openness with respect to the EC, not with respect to third countries. Hence, the Danish economy may well be quite open with respect to, e.g., the other Scandinavian countries.

The distinction between the large and the small member states is also reflected in the differences between the intercountry-spillover and -return effects. Although the small economies are the most open ones, their return effects are weaker than those of the large countries. This represents the strong backward linkages of the small countries with respect to the EC, but the weak backward dependence of the EC with respect to them. In other words, the small countries are more dependent on the EC than the EC is on the small countries (see also Dietzenbacher et al., 1993). For the large member states, the opposite holds. In British Energy, German Manufacturing and Market

[^8]Services, and French Manufacturing, the intercountry-return effects were even stronger than the intercountry-spillover effects. This illustrates the relatively strong backward dependence of the EC on their products.

## 5. Column-wise Search for Reactive Sectors

Section 4 provided an impression about the total influence that EC-sectors may exert on the Leontief-inverse. Now, we can go a step further, and ask which sectors' production multipliers will be most affected by a productivity change in some sector.

Under the assumption that every industry has an equal chance to meet a productivity change, a general ranking of reactive sectors is derived from (12). In this case, Manufacturing, Agriculture and Building are the most reactive sectors, with small mutual differences (see Figures 3 and 4). The other three sectors are not reactive. As argued before, this pattern is explained by the backward linkages of the sectors, and can be derived from the column multipliers and specific linkages with the propulsive sectors.

As mentioned in Section 3.2, each of the $n$ Fields of Influence will have a different set of reactive sectors, the most reactive of course being sector $c$ itself. This is clearly illustrated in the upper, sector by sector, part of Table 3 where the potential effects of productivity changes on the Leontief-inverse are summed over the member states. This may be accomplished without much loss of information as the sector-bysector pattern is essentially the same for each domestic and bilateral (intersectoral) submatrix. Since there are no essential differences between 1970 and 1980, Table 3 presents only the 1980 -results.

The extent to which the most reactive sector is sector $c$ itself, is not the same for each sector. It ranges from over $90 \%$ (Building and Public Services), via about $80 \%$ (Agriculture and Energy) to less than $60 \%$ (Manufacturing and Market Services). Its counterpart is the intersector-spillover effect, which ranges from less than $10 \%$ to over $40 \%$. This also explains the small mutual differences between the reactive sectors in Figure 3 and 4. In 1980, 47\% of the sensitivity to productivity change in Manufacturing would be off-diagonal while for productivity changes in Building this would only be $9 \%$. In the measurement of reactiveness, this compensates for the large differences between the respective production multipliers. Likewise, the low column sensitivity of the Market Services is partly caused by the strong spillover effects of its productivity changes.

These results indeed illustrate that strong linkages with propulsive sectors will make a sector strongly reactive. Moreover, the position of a key sector will be reinforced after a productivity change, especially when it occurs in the sector itself.

The lower part of Table 3 gives the sensitivity of the production multipliers per member state. Here the potential effects of productivity changes are summed over sectors. Hence, we obtain the sensitivity pattern of the member states' production multipliers. It is obvious that there are no big differences between the countries. The United Kingdom and Germany, which were the most propulsive countries, are the most reactive countries too.

The 'landscapes' of column sensitivity are summarized in Figures 3 and 4 for 1970 and 1980, respectively. They give the pattern of the $S_{q}$ 's of (12). The order of sectors and countries is the same as in Figures 1 and 2. This enables a good comparison between propulsive and reactive sectors. The flatness of the figures is due to the compensating effects of the intersector-spillovers discussed above. The figures also illustrate the slightly higher sensitivity of Manufacturing, Agriculture and Building, and of the United Kingdom and Germany. There were only small differences between the 1970 and the 1980 patterns.

Next, we turn to the final step of the analysis, the row-wise evaluation of the Leontief-inverse change.

## 6. Row-wise Search for Dependent Sectors

Under the assumption of an equal importance of demand changes in any sector, Figures 5 and 6 give the patterns of the product or row sensitivity of equation (13), for 1970 and 1980, respectively. They show, on average, the size of the production effects of an equal productivity change over sectors and countries.

The 'landscape' of dependent sectors is not nearly as flat as that of the reactive sectors. The production of Manufacturing goods, especially in the large countries, is most strongly influenced by system-wide productivity developments, followed by the provision of Market services. Energy and Agricultural products take an intermediate position. Building and the provision of Public services are hardly influenced by productivity changes.

Just as in the case of column sensitivity, there is a characteristic pattern of the
effect of productivity changes on the rows of the Leontief-inverse. For each of the $n$ Fields of Influence there is a different set of dependent sectors. This pattern is given in Table 4, which is constructed analogous to Table 3. In the upper part, we indeed see patterns of product sensitivity that are different for each productivity change. For example, for productivity developments in Agriculture, Manufacturing is the most dependent sector, followed by Market Services and Agriculture itself, while for Energy the most dependent sector is Energy itself. On the other hand, a strong general dependency of Manufacturing and Market Services is also evident.

The ranking of dependent member states is not much different from that of the propulsive countries. Only Germany and the United Kingdom have switched their positions. The lower part of Table 4 illustrates the lower variability of sensitivities between the member states, which is also obvious from Figures 5 and 6.

The interpretation of these results is straightforward. As each element of the upper part of Table 4 is calculated by summing the intercountry equivalent of ( $8^{\prime}$ ) over $q^{7}$, it is strongly determined by $g_{p c}$, indicating the specific backward linkage between industry $c$ and $p$. After summing over $c$, so that (13) is obtained, the specific linkages are accumulated, so that all the backward linkages with respect to $p$ makes it sensitive to change. As argued before, however, these latter linkages are strongly related to the size of the sector. A lower level of aggregation may show more varied results.

## 7. Summary and conclusions

In this paper an explorative analysis is made of the impacts of technological change on the multipliers of an intercountry input-output system. Using the notion of the (weighted) Column Fields of Influence, four types of issues were examined: (1) the identification of propulsive sectors by the total impact that their productivity change would have; (2) an analysis of the spatial structure of the inverse-effects of productivity change; (3) the identification of reactive sectors by the sensitivity of individual columns of the Leontiefinverse to EC-wide productivity changes; and (4) the identification of dependent sectors by the sensitivity of individual rows of the Leontief-inverse to EC-wide productivity changes.

[^9]From the nature of the Fields of Influence it is derived that these reactions are positively related to the size of the backward linkages, the specific linkages between pairs of industries, the size of the sectors, and the size and openness of the countries at hand. The application was based on six-sector intercountry input-output tables of the European Community for 1970 ( 5 countries) and 1980 ( 7 countries).

Between the member states there were only small differences, with Great Britain and Germany exerting the strongest impact. The impact of these and the other large countries (France and Italy), however, would be largely domestic, so the rest of the EC (in 1970 and 1980) only feels little influence from their productivity changes. Because of their strong intercountry linkages, technological developments in the smaller countries (Belgium, the Netherlands and Denmark) would have large intercountry-spillovers. This makes their total impact comparable to that of France and Italy. Of the smaller countries, the Danish openness as regards the EC was, like the British, quite small. During the eighties, the openness of these 'new' members might have grown, however.

In each country Manufacturing is both the most propulsive, reactive and dependent sector. Although the linkages of this sector are indeed strong, the impact is also strongly determined by its relative size. Agriculture, Market Services and Building are moderately propulsive. Of these, Market Services is also quite dependent, while the other two sectors are reactive. Finally, Energy and Public Services are hardly propulsive nor reactive, while Energy is quite dependent instead.

The analysis also illustrates the importance of economic openness as regards the sensitivity of some products to productivity changes. Traditionally, an economy is open to manufactured goods, but not to services and agricultural products. This closed nature has further implications than just numerical ones. It also relates to the size of market areas and the economic base (Dicken and Lloyd, 1990; Richardson, 1978). It may even provide a method to the identification of a Fundamental Economic Structure (Jensen et al., 1987, 1988).

A global and qualitative comparison between 1970 and 1980 did not reveal strong developments during the seventies. This might indicate a lack of convergence between the member states. Each country seems to keep some specific technology. True analysis of temporal developments, however, would only be possible when the analysis is conducted on five-countries-only tables, and extended over a longer period. In this case
we will have a more sophisticated incremental, temporal analysis, but lose information about the new member states instead

Some directions of further research can be identified. First, the present analysis is a tentative one. On the one hand, it can be deepened by adopting a lower level of aggregation. This will qualify the results, especially those of the Manufacturing sector. On the other hand, an extended period can be taken into consideration. Second, the present analysis has a strong hypothetical character. This can be overcome by a temporal analysis of the actual differences between pairs of input coefficient matrices ${ }^{8}$. Finally, a decomposition of the actual multiplier changes into the impacts of changes in individual columns may be made.

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Table 1: Propulsiveness of sectors (Volume of Fields of Influence).

| 1970 | D | $F$ | $N L$ | B | $I$ |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Manufacturing | 5.05 | 2.83 | 2.47 | 2.27 | 2.34 |  |  |
| Agriculture | 1.73 | 1.05 | 1.31 | 1.35 | 0.79 |  |  |
| Market Services | 1.96 | 1.28 | 1.20 | 0.69 | 0.94 |  |  |
| Building | 1.02 | 0.90 | 1.02 | 0.88 | 0.83 |  |  |
| Energy | 0.98 | 0.54 | 0.56 | 0.49 | 0.33 |  |  |
| Public Services | 0.60 | 0.57 | 0.41 | 0.38 | 0.36 |  |  |
| 1980 | UK | D | $F$ | $I$ | $N L$ | DK | B |
| Manufacturing | 3.60 | 4.39 | 2.69 | 3.03 | 2.53 | 1.89 | 2.14 |
| Agriculture | 1.83 | 1.33 | 1.34 | 1.00 | 1.33 | 1.23 | 1.26 |
| Market Services | 1.62 | 1.68 | 1.38 | 1.37 | 1.06 | 1.15 | 0.76 |
| Euilding | 1.58 | 0.96 | 0.84 | 0.98 | 1.38 | 1.02 | 0.87 |
| Energy | 1.31 | 1.09 | 0.52 | 0.38 | 0.42 | 0.72 | 0.39 |
| Public Services | 0.75 | 0.60 | 0.44 | 0.40 | 0.38 | 0.42 | 0.31 |

Figure 1: Propulsiveness of sectors, 1970.


Figure 2: Propulsiveness of sectors, 1980.


Table 2: Spatial structure of Volume of Fields of Influence (\%).

| Country | Sector | 1970 |  |  |  | 1980 |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  |  | $P(C C)$ |  | P(Cs) |  | $P(C C$ |  | P(Cs) |  |
|  |  |  | $P(r C)$ |  | P(ts) |  | $P(r C)$ |  | P(ts) |
| United | Manufacturing |  |  |  |  | 73 | 13 | 12 | 2 |
| Kingdom | Agriculture |  |  |  |  | 89 | 8 | 3 | 0 |
|  | Market Services |  |  |  |  | 85 | 8 | 6 | 1 |
|  | Building |  |  |  |  | 90 | 9 | 1 | 0 |
|  | Energy |  |  |  |  | 75 | 6 | 17 | 1 |
|  | Public Services |  |  |  |  | 89 | 9 | 2 | 0 |
| Germany | Manufacturing | 64 | 9 | 23 | 3 | 59 | 10 | 26 | 5 |
|  | Agriculture | 87 | 8 | 5 | 0 | 82 | 12 | 5 | 1 |
|  | Market Services | 80 | 7 | 12 | 1 | 76 | 8 | 15 | 2 |
|  | Building | 90 | 9 | 1 | 0 | 87 | 12 | 1 | 0 |
|  | Energy | 81 | 11 | 7 | 1 | 72 | 18 | 8 | 2 |
|  | Public Services | 89 | 10 | 1 | 0 | 86 | 12 | 1 | 0 |
| France | Manufacturing | 70 | 12 | 15 | 3 | 63 | 16 | 17 | 4 |
|  | Agriculture | 83 | 9 | 8 | 1 | 79 | 12 | 8 | 1 |
|  | Market Services | 85 | 7 | 7 | 1 | 79 | 10 | 10 | 1 |
|  | Building | 86 | 13 | 0 | 0 | 80 | 19 | 1 | 0 |
|  | Energy | 87 | 10 | 3 | 0 | 78 | 16 | 5 | 1 |
|  | Public Services | 92 | 8 | 0 | 0 | 89 | 11 | 1 | 0 |
| Italy | Manufacturing | 77 | 15 | 7 | 1 | 72 | 18 | 8 | 2 |
|  | Agriculture | 88 | 10 | 2 | 0 | 85 | 13 | 2 | 0 |
|  | Market Services | 90 | 7 | 4 | 0 | 87 | 8 | 5 | 0 |
|  | Building | 89 | 11 | 0 | 0 | 86 | 13 | 0 | 0 |
|  | Energy | 85 | 12 | 2 | 0 | 82 | 15 | 2 | 0 |
|  | Public Services | 92 | 7 | 0 | 0 | 90 | 10 | 0 | 0 |
| The | Manufacturing | 51 | 38 | 6 | 5 | 50 | 35 | 9 | 6 |
| Netherlands | Agriculture | 75 | 21 | 3 | 1 | 73 | 22 | 4 | 1 |
|  | Market Services | 62 | 31 | 5 | 2 | 68 | 20 | 9 | 3 |
|  | Building | 57 | 42 | 0 | 0 | 67 | 32 | 1 | 0 |
|  | Energy | 70 | 25 | 4 | 1 | 43 | 39 | 9 | 8 |
|  | Public Services | 72 | 28 | 0 | 0 | 78 | 21 | 1 | 0 |
| Denmark | Manufacturing |  |  |  |  | 69 | 29 | 2 | 1 |
|  | Agriculture |  |  |  |  | 76 | 24 | 1 | 0 |
|  | Market Services |  |  |  |  | 84 | 15 | 1 | 0 |
|  | Building |  |  |  |  | 77 | 23 | 0 | 0 |
|  | Energy |  |  |  |  | 49 | 51 | 0 | 0 |
|  | Public Services |  |  |  |  | 83 | 17 | 0 | 0 |
| Belgium | Manufacturing | 44 | 42 | 7 | 7 | 37 | 49 | 6 | 8 |
|  | Agriculture | 73 | 24 | 2 | 1 | 66 | 32 | 1 | 1 |
|  | Market Services | 67 | 27 | 4 | 2 | 66 | 28 | 4 | 2 |
|  | Building | 61 | 38 | 0 | 0 | 56 | 44 | 0 | 0 |
|  | Energy | 68 | 29 | 2 | 1 | 59 | 34 | 5 | 3 |
|  | Public Services | 65 | 35 | 0 | 0 | 65 | 35 | 0 | 0 |

Table 3: Sensitivity of output multipliers to productivity change, 1980.

| Multiplier sensitivity: | Productivity change in Community sector |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | Manufacturing | Agriculture | Market Serv. | Building | Energy | Public Serv. |
| Manufacturing | 10.85 | 0.84 | 0.97 | 0.09 | 0.29 | 0.07 |
| Agriculture | 3.14 | 7.94 | 0.80 | 0.12 | 0.30 | 0.09 |
| Market Services | 1.22 | 0.12 | 5.41 | 0.18 | 0.19 | 0.05 |
| Building | 3.40 | 0.26 | 0.95 | 6.92 | 0.17 | 0.04 |
| Energy | 0.53 | 0.04 | 0.32 | 0.13 | 3.72 | 0.02 |
| Public Services | 1.15 | 0.11 | 0.59 | 0.18 | 0.15 | 3.02 |
| United Kingdom | 3.42 | 1.81 | 1.56 | 1.57 | 1.08 | 0.74 |
| Germany | 3.31 | 1.30 | 1.48 | 0.96 | 1.05 | 0.60 |
| France | 2.50 | 1.24 | 1.30 | 0.83 | 0.53 | 0.44 |
| Italy | 3.04 | 1.02 | 1.37 | 0.98 | 0.40 | 0.40 |
| The Netherlands | 2.94 | 1.34 | 1.10 | 1.37 | 0.44 | 0.39 |
| Denmark | 2.40 | 1.27 | 1.23 | 1.03 | 0.89 | 0.42 |
| Belgium | 2.66 | 1.33 | 0.99 | 0.88 | 0.44 | 0.32 |

Figure 3: Reactiveness of sectors, 1970 (multiplier sensitivity)


Figure 4: Reactiveness of sectors, 1980 (multiplier sensitivity)


Table 4: Sensitivity of sectoral production to productivity change, 1980

|  | Productivity change in EC sector |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Production sensitivity: | Manufacturing | $\begin{gathered} \text { Agri- } \\ \text { culture } \end{gathered}$ | Market Serv. | Buil- <br> ding | Energy | Public Serv. |
| Manufacturing | 10.63 | 4.25 | 2.58 | 3.98 | 0.86 | 1.27 |
| Agriculture | 2.41 | 1.84 | 0.29 | 0.34 | 0.07 | 0.13 |
| Market Services | 4.59 | 1.87 | 4.56 | 1.88 | 0.85 | 1.07 |
| Building | 0.26 | 0.18 | 0.43 | 0.85 | 0.24 | 0.22 |
| Energy | 1.92 | 0.91 | 0.95 | 0.48 | 2.73 | 0.38 |
| Public Services | 0.45 | 0.26 | 0.22 | 0.10 | 0.08 | 0.22 |
| United Kingdom | 3.79 | 1.93 | 1.69 | 1.66 | 1.63 | 0.76 |
| Germany | 5.42 | 1.67 | 1.87 | 1.44 | 1.07 | 0.68 |
| France | 3.18 | 1.48 | 1.45 | 0.96 | 0.55 | 0.48 |
| Italy | 2.87 | 0.99 | 1.35 | 0.99 | 0.37 | 0.40 |
| The Netherlands | 2.19 | 1.29 | 1.01 | 1.13 | 0.49 | 0.38 |
| Denmark | 1.41 | 0.96 | 1.00 | 0.81 | 0.36 | 0.35 |
| Belgium | 1.41 | 0.99 | 0.66 | 0.64 | 0.36 | 0.25 |

Figure 5: Dependence of sectors 1970. (production sensitivity)


Figure 6: Dependence of sectors 1980. (production sensitivity)


## An Equilibrium Analysis of Regional Industrial Diversification

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#### Abstract

Regions are characterized as open activity models with endowments of natural resources and labour, and subjected to both productivity and price shocks. Prices of differentiated commodities are endogenous. Small industrial diversification policies are partially ranked by the direction in which they point away from the current allocation in mean-variance space. The analysis is applied to the Saskatchewan economy as revealed in the 1984 input-output tables. We conclude that there is some support for the view that the observed market allocation of activity reflects some specialization in the direction of comparative advantage, and that this specialization entails some risk.


[^11]
#### Abstract

... I will deliver my opinion concerning our Clothing, which although it is the greatest Wealth and best Employment of the Poor of this Kingdome, yet neverthelesse we may peradventure employ our selves with better Safety, Plenty, and Profit in using more Tillage and Fishing, than to trust so wholly to the making of Cloth; for in times of War, or by other occasions, if some forraign Princes should prohibit the use thereof in their dominions, it might suddenly cause so much poverty and dangerous uproars, especially by our poor people, when they should be deprived of their ordinary maintenance, which cannot so easily fail them when labours should be divided into the said diversity of employments ... Munn (1664, 73); quoted in Hollander (1973, 55).


## 1 Introduction

Specialized regional economic structures are sometimes argued to expose regions to unacceptable risk whereas more diversified economies would enjoy greater stability. The effort to make this argument precise - to develop a useful model of regional diversification - has a long and uneven history, both in the sense of providing a conceptual framework within which issues can be defined and explored and in the sense of developing an empirically tractable structure within which the conceptual issues can be eva! uated (see Richardson (1985) for a recent review or Gilchrist and St. Louis (1991) for an overview and further references). Moreover, the possibility of compromising regional prosperity through a failure to exploit comparative advantages, though obvious, is not always accorded parallel consideration.

In this paper, we develop a simple but tractable model of regional income formation when a small region engaged in interregional trade is exposed to intra-regional productivity shocks and extra-regional price shocks. Commodities are distinguished on the basis of origin; domestic varieties of differentiated commodities trade at endogenously formed market clearing prices, prices which depend in part on realized domestic income. This model is motivated by the literature on trade under uncertainty (see Pomery (1984) for a recent survey) and is a generalization of the model in

Gilchrist and St. Louis (1991).

With products differentiated on the basis of origin - the Armington (1969) assumption - our analysis is embedded in a market equilibrium in which the number of industries active in a trading region can exceed the number of primary factors (see Whalley and Yeung (1984) for a survey and ten Raa and Chakraborty (1991) for an innovative alternative). Nondifferentiated products (wheat, for example) are produced in equilibrium to the extent that they exploit an immobile regional resource (mineral deposits, for example).

This framework is then applied to the economic structure revealed for the province of Saskatchewan in the recently released 1984 input-output tables. We conclude that the concern that specialization and trade exposes the region to instability is well taken but also that the aforementioned possibility of compromising a comparative advantage is real.

## 2 An equilibrium model

We model a region as a small open economy in which all commodities are potentially tradeable. Capital is mobile on regional and interregional markets. Labour is mobile on regional but not interregional markets. ${ }^{1}$ Natural resources are industry and region specific ${ }^{2}$ but rates of utilization are variable (at least reducible). The region is small relative to the national economy - foreign ${ }^{3}$ commodity prices and the rate

1 The model to be developed below assumes fixed proportions and constant returns to scale. All quantities are scaled to per worker magnitudes. Input allocations are then determined by the proportion of the labour force employed in each industry. If natural resource constraints are not binding, variations in total employment through growth, reduced unemployment, or migration will not affect the results. The terms labour force and employment are used synonymously.
2 Specificity effectively distinguishes as many natural resources as the number of industries utilizing natural resources as primary inputs.
3 We apply the term foreign to the world beyond regional boundaries - all other regions and countries, and we apply the term domestic to the region itself.
of interest are parametric to the region. Capital mobility implies that residents in the region are able to diversify their portfolios on national or international markets to obtain a rate of return that does not depend on the profitability of capital invested within the region. Regional labour income and resource rents reflect regional fortunes however, and the level and stability regional GNP is the focus of diversification policies.

The region is modelled from the perspective of a policy-maker evaluating alternative production allocations before commodity prices or technological shocks are known. Intermediate inputs, capital, labour, and natural resources are committed to production before uncertainty is resolved. We assume a constant returns to scale technology with fixed proportions for each of $J$ industries. Constant returns to scale implies that the regional technology can be scaled by employment to express all magnitudes in per worker terms. With fixed proportions the level of industry activity is proportional to the use of any input. All industries employ labour; the pattern of industry activity is then indexed by the commitment of labour to each industry. Assuming labour to be homogeneous and normalizing the regional labour supply to one unit, production commitments are fixed by the vector ${ }^{4} \lambda$ of proportions $\lambda_{j}, J \in J, J=\{1, \ldots, J\}, 5$ of the labour force allocated to each industry, where $0 \leq \lambda_{j} \leq 1$ and $\sum_{j \in J} \lambda_{j}=1$.

The set of all commodities is $L=\{1, \ldots, L\}$ within which we distinguish two types of commodities: non-differentiated commodities, indexed $i \in N, N=$ $\{1, \ldots, n\}$, and differentiated commodities, indexed $i \in D, D=\{n+1, \ldots, L\}$. Non-differentiated commodities are produced domestically and elsewhere in the world, and trade at the same price in both markets. Differentiated commodities are produced in the domestic and foreign markets, but the domestic and foreign products are distinquished on the basis of origin. Thus the domestic and foreign varieties of commodity $1,1 \in D$, can trade at distinct prices. This is consistent with the Armington (1969) approach.

4 All vectors are column vectors; the transpose of a vector or matrix $x$ is denoted $x^{T}$.
5 We economize on notation by denoting both the set $J$ (and the set $L$, defined below) and the number of elements it contains by the same symbol.

Non-traded commodities are included as a special case of differentiated commodities.

Each industry produces a vector of $L$ commodities. In industry $j$, the quantity of commodity $i$ produced per unit of labour is $\tau, \mathrm{b}_{1} \mathrm{j}$ and the gross output of commodity $i$ is $\tau, b_{i} \lambda_{j}$, ifL. We interpret $\tau_{j}$ as a region and industry specific productivity shock, a realization of the random variable $\tau$, which takes values in $R_{+}$. The random vector $\tau=\left(\tau_{1}, \ldots, \tau_{j}\right)^{\boldsymbol{T}}$ has a stationary distribution with means $E\left(\tau_{j}\right)=1, j \in J$, and a finite covariance matrix $\operatorname{Cov}\left(\tau, \tau^{T}\right)=\Sigma_{\tau}$. Thus at the time resource allocations are determined in industry $j, b_{j}=\left(b_{1 j}, \ldots, b_{L j}\right)^{r}$ is the expected output vector per unit of labour. ${ }^{6}$ We assume that the $\tau_{1}$ are mutually independent; thus $\Sigma_{\tau}$ is diagonal. This assumption is sensitive to the level of aggregation in the model.

Production in industry $J$ requires the intermediate input of commodity i in the amount $a_{1 j}$, ieL, per unit of labour. Denoting the vector of intermediate inputs per unit of labour in industry $j$ by $a_{j}=$ $\left(a_{1 j}, \ldots, a_{L j}\right)^{T}$, the intermediate input vector in industry $j$ is $a_{j} \lambda_{j}$. The intermediate input of commodity 1 may be purchased from domestic producers or imported from foreign producers (i.e., from outside the region). In industry $J$, the proportion of the intermediate use of commodity 1 purchased from foreign suppliers is $\gamma_{1 j}$, ieL. Thus $\left(1-\gamma_{1 j}\right) a_{i j}$ is purchased locally and $\gamma_{1} j_{1}$, is imported. This is consistent with the Armington (1969) approach if the intermediate input mixture is nested Leontief.

The vector of prices of domestically produced commodities is $p=$ $\left(p_{1}, \ldots, p_{L}\right)^{T}$. The vector of foreign commodity prices ${ }^{7}$ is a realization $\pi$

6 The relationship of the vectors $b$, and $a_{j}\left(a_{j}\right.$ is defined below) to standard input-output concepts is made explicit in Section 4.1. The notation introduced here facilitates two distinctions: values observed in input-output tables are separated into prices and quantities, with productivity shocks affecting only the latter, and activities are scaled to per worker magnitudes.
7 Commodity prices are producer prices, as measured in the rectangular input-output tables, for example.
of the random vector $\pi$ taking values in $\mathbb{R}_{+}^{L}$. Let $e$ be an $L \times 1$ unit vector. We assume that $\pi$ has a stationary distribution, mean vector $E(\pi)=e$, a finite covariance matrix $\operatorname{Cov}\left(\pi, \pi^{T}\right)=\Sigma_{\pi}$, and that $\pi$ and $\tau$ are independent. Since we assume that the region is a small open economy, $\pi$ is parametric to the region. Domestically produced units of a non-differentiated commodity trade at the world price, i.e., $p_{1}=\pi_{1}, i \in N$. Given a realized productivity shock vector $\tau$ and a realized foreign price vector $\pi$, the value of regional net output (per worker) in a non-differentiated commodity is

$$
z_{i}=\sum_{j \in J} \pi_{i}\left(\tau, b_{i j}-a_{i j}\right) \lambda_{j}, \quad i \in N
$$

The prices $p_{1}, i \in D$, of domestically produced differentiated comodities are determined endogenously by expost market clearing. Domestic final demand for the domestically produced variety of commodity in assumed to be Cobb-Douglas and given by $\delta_{1} y / p_{1}, \delta_{1}>0$, $i \in D$, where $y$ is GNP per worker. ${ }^{8}$ We assume $\sum_{1 \in D} \delta_{i}<1$. Foreign demand for the domestically produced variety of commodity $i$ is assumed to be $\phi_{1} \pi_{1} / p_{1}, \phi_{1} \geq 0$, $i \in D$. This functional form is tractable and captures the dependency of foreign demand for the domestic variety on the relative price of the foreign and domestic varieties. ${ }^{9}$ We assume that the $\phi_{1}$ are non-stochastic. A non-traded commodity is simply a special case, a differentiated commodity which is neither exported nor imported, i.e., $\phi_{1}=0, \gamma_{1 j}=0, j \in J$, and $\delta_{1} y$ is total final expenditure on the commodity.

Market clearing for a differentiated product requires

$$
\sum_{j \in J}\left[\tau, b_{i j}-\left(1-\gamma_{1 j}\right) a_{1 j}\right] \lambda_{j}=\left(\delta_{1} y+\phi_{1} \pi_{i}\right) / p_{1}, \quad 1 \in D .
$$

The value of regional net output (per worker) in a differentiated product is

$$
z_{1}=\sum_{j \in J}\left\{p_{1}\left[\tau, b_{1 j}-\left(1-\gamma_{1 j}\right) a_{i j}\right]-\pi_{1} \gamma_{1}, a_{i j}\right\} \lambda_{j}, \quad i \in D .
$$

Using market clearing,

[^12]$$
z_{i}=\delta_{1} y+\phi_{1} \pi_{1}-\sum_{j \in J} \pi_{1} \gamma_{1 j} a_{i j} \lambda_{j}, \quad i \in D
$$

The cost of capital in industry $j$ is $\rho_{j}$, and $\rho=\left(\rho_{1}, \ldots, \rho_{j}\right)^{T}$. We assume that $\rho$ is non-stochastic. Let $k=\left(k_{1}, \ldots, k_{j}\right)^{T}$ be the vector of capital requirements per unit of labour. The cost of capital employed in industry $j$ is then $\rho_{j} k_{j} \lambda_{j}, j \in J$, and the cost of capital employed in the region is $(\rho \circ k)^{T} \lambda$, where $\circ$ denotes the Hadamard product.

Regional value-added per worker is $v=\sum_{i \in I} z_{i} .{ }^{10}$ Then $v-(\rho \circ k)^{T} \lambda$ is the component of regional income which is created within the region using regional labour and natural resources. ${ }^{11}$ Adding $r$, the income (per worker) accruing to regional residents from capital invested within the region or elsewhere, expost regional income per worker is $y=v-(p \circ k){ }^{T} \lambda+r$. Thus $r-(\rho \circ k)^{T} \lambda$ is regional net capital income per worker. In order to separate the analysis of the regional economic structure from the portfolio choices of individual regional residents, we assume that $r$ is nonstochastic.

Define the following notation:
$B$, an $L \times J$ matrix with elements $b_{1 j}, i \in N, j \in J$, and 0 elsewhere,
$\beta$, an $L x J$ matrix with elements $\left(\tau_{j}-1\right) b_{i j}, i \in N, j \in J$, and 0 elsewhere,
$C$, an $L \times J$ matrix with elements $b_{1 j}-a_{1 j}, i \in N, j \in J$, and $-\gamma_{1 j} a_{1 j}, i \in D, j \in J$, and
$\phi$, an $L \times 1$ vector with elements $\phi_{1}, i \in D$, and 0 elsewhere.

Using these definitions, expost regional income per worker is

$$
y=(1-\delta)^{-1}\left(\pi^{\mathrm{T}} \beta \lambda+\pi^{\mathrm{T}} C \lambda+\pi^{\mathrm{T}} \phi+r-(\rho \circ \mathrm{k})^{\mathrm{T}} \lambda\right)
$$

where $\delta=\sum_{i \in D} \delta_{i}$. Then expected regional income per worker, $E(y)$, is

$$
\mu=(1-\delta)^{-1}\left(e^{T} C \lambda+u^{T} \phi+r-(\rho \circ k)^{T} \lambda\right)
$$

and the variance of regional income per worker, $\operatorname{Var}(y)$, is
10 This identity holds for regions only if final output includes regional net exports.
11 We interpret value-added net of the cost of capital as income for regional residents. Taxes and other interregional transfers would be included in a more complete analysis.

$$
\sigma^{2}=(1-\delta)^{-2}\left\{\lambda^{T}\left[\Sigma_{\tau} \circ B^{T}\left(\Sigma_{\pi}+e e^{T}\right) B+C^{T} \Sigma_{\pi} C\right] \lambda+2 \phi^{T} \Sigma_{\pi} C \lambda+\phi^{T} \Sigma_{\pi} \phi\right\}
$$

Technology shocks add to the diagonal of the quadratic component of the variance, and through the presence of the unit matrix ee ${ }^{T}$, induce variability even if world prices are stable. If world prices are variable, technology shocks and world price shocks interact multiplicatively.

## 3 Diversification policies

We assume that diversification policies - reallocations of industrial activity - are intended to improve the performance of the regional economy. However we do not define an explicit objective function by which the policy-maker evaluates policy alternatives but instead assume that expected income per worker and its stability, as measured by the variance, are included in the arguments of whatever criterion is applied. 12 We then investigate the implications of policy alternatives for the mean and variance of regional income to obtain partial policy rankings on the assumption that the criterion is locally increasing in expected regional income and decreasing in the variance of regional income.

The mechanisms by which policy-makers might effect a redeployment of resources are not specified. Instead, we investigate consequences with a focus on policies which effect small reallocations of activity among industries. Thus we describe policies in terms of their effects on industry activity and define a diversification policy as a small variation $d \lambda$ in the allocation of activity such that $0 \leq \lambda_{j}+d \lambda_{j} \leq 1$ and $\sum_{j \in J} d \lambda_{j}=0$. Not all reallocations are feasible: the availability of natural resources constrains the opportunities for expansion in certain industries, for example.

The impact of a policy $d \lambda$ - a diversification in the direction $d \lambda$ - on the mean and variance of income is

12 A full analysis would incorporate regional consumption patterns. We focus on income and its relationship to the pattern of regional production since this is the primary concern of industrial diversification policies.

$$
d \mu=(1-\delta)^{-1}\left(e^{T} C-(\rho \circ k)^{T}\right) d \lambda
$$

and

$$
\mathrm{d} \sigma^{2}=2(1-\delta)^{-2}\left\{\lambda^{T}\left[\Sigma_{\tau} \circ \mathrm{B}^{\mathrm{T}}\left(\Sigma_{\pi}+e e^{T}\right) \mathrm{B}+\mathrm{C}^{\mathrm{T}} \Sigma_{\pi} C\right]+\phi^{T} \Sigma_{\pi} C\right\} \mathrm{d} \lambda .
$$

This formulation does not restrict the analysis of diversification policy to variations in the level of activity of current industries and there are persuasive arguments that it should not (Richardson 1985). New technologies for producing the current varieties of commodities - more efficient plants or even plants relocated into the region - can be included as distinct industries which do not operate in the initial allocation (i.e., $\lambda_{j}=0$ for these industries). Diversification policy includes the development of such industries. Domestic production of foreign varieties of commodities can be incorporated by including the foreign variety in the set of non-differentiated commodities which can be produced in the region. Restricting the analysis to variations in the allocation of activity within the currently observed industrial structure, as we do below, is not forced by the model but by the data with which we can implement the model. Moreover, exploring the possibilities available within the current technological structure is a logical precursor to the richer menu just suggested.

We focus our attention on two particular characterizations of diversification policies. Each has intuitive appeal and embodies a particular view of regional diversification. ${ }^{13}$

### 3.1 Industry dependency

Diversification policy can be aimed at reducing specialization in a relatively unstable industry. World demand variability (reflected in $\Sigma_{n}$ ) and technology shocks (reflected in $\Sigma_{\tau}$ ) induce policy-makers to consider creating alternative opportunities in other industries. ${ }^{14}$ To give a 13 For the special case in which all commodities are non-differentiated, further interpretations are given in Gilchrist and St. Louis (1991). 14 For example: "Diversification. The word has been the Holy Grail of Alberta governments for decades. Their quest is to broaden the base of the provincial economy and lick the boom and bust cycles that have haunted
concreteness to what follows, we might think of diversification intended to absorb into manufacturing and service industries labour released from resource industries.

Though actual policies will undoubtedly target both industry sectors and the industry mix within sectors, we confine our analysis to policies that preserve relative employment proportions within sectors. Partition the set of industries $J$ into 3 groups: expanding industries $J_{e}$ for which $d \lambda_{j}>0$, contracting industries $J_{c}$, for which $d \lambda_{j}<0$, and the rest. If the rate of employment expansion in the expanding sector is $\alpha$, sector targetting policies which preserve full employment satisfy:

$$
\begin{aligned}
d \lambda_{j}= & \alpha \lambda_{j}, j \in J_{0}, \\
& -\alpha \lambda_{j}\left(\sum_{j \in J_{e}} \lambda_{j}\right) /\left(\sum_{j \in J_{c}} \lambda_{j}\right), j \in J_{c}, \text { and } \\
& 0, \text { otherwise. }
\end{aligned}
$$

Several special cases emerge within this definition. The aforementioned shift from the resource sector to the manufacturing and service sector is one example of broadly defined policy. Another is picking winners, which we stylize as $J_{e}=\left\{j^{*}\right\}$ - the winner - with $J_{c}$ comprising all other industries. Intuitively, the policy-maker promotes a particular industry bu leaves the diversion of resources to the market which is presumed to draw equi-proportionately on all other industries. A third will also pick the contracting industry. For example, a policy-maker may be concerned to develop opportunities in a specific industry - say "high-tech" manufacturing (and perhaps also to entice it into rural locations) - to provide an alternative to a relatively unstable agriculture industry. Industry targetting in which the policy-maker picks both the expanding and contracting industries is perhaps the fundamental policy.

### 3.2 Self-gufficiency

Industry targetting is not the only interesting characterization of policy, however. Directing activity away from specialized export

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single-commodity, prairie economies since Confederation." Cernetig, M., 2
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May 1991, Globe and Mail, Toronto, p. B1.
industries and toward import competing industries - seeking regional selfsufficiency - pursues domestic stability by reducing exposure to external market forces. ${ }^{15}$ For example, the Western Diversification Program enacted by the Canadian government in 1987 created a ( $\$ 1.2$ billion) Western Diversification Fund. Among the criteria for project support was the replacement of foreign imports.

Following Leontief (1953), let $\theta_{j}^{x}$ be the share of industry $J$ in the value of regional exports and $\theta_{j}^{m}$ be the share of industry $J$ in the value of regional imports. Define the vector $\theta$ by $\theta_{j}=\theta_{j}^{m}-\theta_{j}^{x}, j \in J$. Then a small movement toward self-sufficiency is given by $d \lambda=\alpha \theta$. This approach allows for cross-hauling.

## 4 An application

### 4.1 Data

The model is implemented for the economic structure revealed in a special aggregation of the 1984 Input-Output Tables for Saskatchewan developed by Statistics Canada. This aggregation falls between the "small" and the "medium" industry aggregations and is an aggregation of the "small" commodity aggregation defined by Statistics Canada. ${ }^{16}$ The industries are listed in Table 1.

15 The Government of Saskatchewan has a Department of Economic Diversification and Trade, for example. Though they might prefer to interpret their mandate as a quest for a new comparative advantage, their origins lie in concerns similar to those of the Government of Alberta. Of course, we would not suggest that their policies conform to our characterization.
16 The small tables obscure industrial diversity and the medium tables are censored. Three industries, Transportation Margins, Office Operating and Lab Equipment, and Travel Advertising and Promotion, are dummy sectors employing no labour and have been deleted (of course, the corresponding commodities remain). Owner-Occupied Dwellings were moved from the business to the household sector. Government Royalties on Natural Resources were reallocated to value-added in the Mining and Oil and Gas industries, and the corresponding industry deleted.

There are 27 commodities, listed in Table $A 2$ in the Appendix. Of these, the first 7 - the natural resource products - are modelled as nondifferentiated commodities. Statistics Canada identifies potash as a fertilizer, a manufactured product, and in the special commodity aggregation avallable for this study, fertilizers are aggregated with Chemicals and Refined Petroleum Products. Because Saskatchewan has a significant presence in the potash market, the medium aggregation 1984 Saskatchewan Input-Output Tables and trade data for Saskatchewan ${ }^{17}$ were used to isolate potash and include it with Non-metallic Minerals. ${ }^{18}$ The remaining 20 commodities - the manufactured products and services - are modelled as differentiated commodities.

The Saskatchewan economy is small within Canada, producing slightly less than $4 \%$ of national GDP, and price indices for Canada are assumed to be independent of Siskatchewan activity. National nominal and deflated output data corresponding to the input-output commodity aggregation for the years 1961-1987 was provided by Statistics Canada and commodity price indices were obtained by dividing current dollar commodity outputs by the constant dollar counterparts. For Non-metallic Minerals, we replaced the implicit price index in the input-output data with the Saskatchewan export price for potash. ${ }^{19}$ These nominal price indices, deflated by the Canadian GDP deflator, were used to compute an estimate of $\Sigma_{\pi}$ as the estimated covariance matrix of the residuals from first-order autoregressions of the commodity price indices. ${ }^{20}$ The estimated matrix $\Sigma_{\pi}$ is in the Appendix in Table A2. We assume that in 1984, $\pi_{1}=1$ for all 1 .

Since comparable data from which productivity shocks could be estimated were not available, the results presented below impose $\operatorname{Var}\left(\tau_{\mathrm{f}}\right)=0$, for all $j \neq 1$, where industry 1 is Agriculture. Based on spring wheat yields per 17 Government of Saskatchewan (1991).
${ }^{18}$ Production of other Non-metallic Minerals is small relative to potash. 19 Government of Saskatchewan (1991).
${ }^{20}$ The appropriate characterization of uncertainty is not resolved in this paper. Limiting the information set available to firms to once-lagged own prices is restrictive, however.
acre in Saskatchewan for 1951-1988 (Saskatchewan Agriculture and Food (1989), Table 29), a reasonable estimate of the coefficient of variation for crops is 0.05 . Then $\operatorname{Var}\left(\tau_{1}\right)$ is 0.05 adjusted for the share of crops in agricultural output. We assume that in $1984, \tau_{j}=1$ for all j .

The allocation of labour ( $\lambda$ ) in 1984 is the vector of industry shares of employment, based on an unpublished tabulation by Statistics Canada. This tabulation is censored for manufacturing industries however; within this sector, employment was apportioned using shares of value-added by labour. ${ }^{21}$ The employment shares are in Table 1 . The substantial specialization in agriculture and the small manufacturing sector are of concern to Saskatchewan policy-makers.

Capital stocks by industry are published for Canada (Statistics Canada, Catalogue 13-211) but not for Saskatchewan. Accordingly, Saskatchewan was apportioned a share of the national net capital stock in each industry using the 1984 share of Saskatchewan gross output in national gross output in each industry. These capital stocks were scaled by industry employment to obtain the vector $k$. The rate of interest is the real yield on longterm corporate bonds over 1978-1990 (Bank of Canada, Tables F1 and H4). The cost of capital in each industry $\left(\rho_{j}\right)$ is the rate of interest plus the rate of depreciation in each industry (capital consumption allowances per dollar of net capital stock). Agricultural capital includes land, for which the rate of depreciation is assumed to be 0. 22 Data limitations prevent the inclusion of industry specific risk premia.

We benchmark the model to the observed 1984 Saskatchewan economy. The commodity by industry "use" matrix $U$ and the industry by commodity "make" matrix $V$ were scaled by 1984 employment in the business-sector. The assumption that, in 1984, $\pi_{1}=1$ for all 1 and $\tau_{j}=1$ for all $j$ implies that $p_{1}=1$ for all is an equilibrium price vector. Then given $\lambda$, the 21 Labour income was deemed to include a share of the income from unincorporated business. Indirect taxes and subsidies were included in labour income.
22 We are grateful to Hartley Furtan for providing us with an estimate of the value of agricultural land in 1984.

Table 1
Allocation of Labour by Industry Saskatchewan, 1984

|  | Employment | Self-sufficiency |
| :---: | :---: | :---: |
| Resources |  |  |
| Agriculture | 26.85 | -27.59 |
| Fishing | 0.06 | -0.04 |
| Forestry | 0.30 | -0.01 |
| Mining | 2.35 | -10.65 |
| Oil \& Gas | 0.74 | -11.29 |
|  | 30.31 | -49.58 |
| Manufacturing |  |  |
| Food \& Beverages | 1.96 | 3.58 |
| Rubber, Leather, \& Plastics | 0.05 | 1.96 |
| Textiles | 0.10 | 3.01 |
| Wood, Furniture, \& Paper | 0.92 | 2.55 |
| Printing \& Publishing | 0.82 | 1.02 |
| Primary \& Fabricated Metals | 1.67 | 7.02 |
| Transportation Equipment | 0.17 | 0.94 |
| Electrical Products | 0.58 | 3.54 |
| Non-metallic Minerals | 0.39 | 1.53 |
| Petroleum Refining | 0.19 | 7.24 |
| Chemical Products | 0.22 | 2.09 |
| Miscellaneous Manufacturing | 0.23 | 2.62 |
|  | 7.30 | 37.08 |
| Services |  |  |
| Construction | 6.76 | 0.03 |
| Transportation \& Storage | 5.20 | -1.16 |
| Communications | 2.94 | 0.44 |
| Electrical Power \& Gas | 1.14 | -0.47 |
| Wholesale Trade | 6.19 | 2.33 |
| Retail Trade | 16.82 | 2.91 |
| Finance, Insurance, Real Estate | 5.83 | 4.26 |
| Commercial Services | 17.54 | 4.28 |
|  | 62.40 | 12.61 |

Note: Employment is the vector $\lambda$ and self-sufficiency is the vector $\theta$, in each case multiplied by 100 .
$a_{1 j}$ and $b_{1 j}$ are determined directly from the input-output matrices using $\left[p_{1}\left(1-\gamma_{1 j}\right) a_{1 j}+\pi_{1} \gamma_{1 j} a_{1 j}\right] \lambda_{j}=u_{i j}$ and $p_{1} \tau_{j} b_{i j} \lambda_{j}=v_{j 1}$.

For the differentiated commodities, we assume that $\gamma_{1 j}=\gamma_{1}, j \in J$, with $\gamma_{1}$ the average import share for each commodity 1 . The $\delta_{1}$ were computed from domestic final demand and the $\gamma_{1}, 23$ and the $\phi_{1}$ were computed from exports. The multiplier, $(1-\delta)^{-1}$, was 1.639 .

Let $m$ and $x$ be vectors in which the elements $m_{1}$ and $x_{1}$, $i \in L$, are the shares of commodity i in total regional imports and total regional exports, respectively. Given the industry by commodity domestic market share matrix D, we define vectors of industry import and export shares by Dm and Dx. Then $\theta=D(m-x)$ is the vector required for a diversification in the direction of self-sufficiency. Unfortunately, the commodity Machinery and Equipment was aggregated with Automobiles and Trucks in the data. Since Saskatchewan has a large Primary and Fabricated Metals industry and a small Transportation Equipment industry, the D matrix forces the Primary and Fabricated Metals industry to expand to replace imported Automobiles and Trucks. Moreover, it makes little sense to force the observed Transportation Equipment industry to produce Automobiles and Trucks. Accordingly, Automobiles and Trucks were removed from the trade data before computing the $m$ and $x$ vectors to which the $D$ matrix was applied. The resulting shares are in Table 1.

### 4.2 Results

In the allocation observed in Saskatchewan in 1984, the standard deviation of income per employed worker was $\$ 1952$ and expected income per employed worker was $\$ 29816 .{ }^{24}$ The results reported below are deviations from this outcome. In each case, employment in the targetted sector was increased by $0.1 \%$ of the provincial labour force. Though this imposed 23 Though Construction is the only non-traded commodity, trade is negligible in Office Lab and Cafeteria Supplies, in Travel Advertising and Promotion, and in Retail Margins. However, the latter was aggregated in the data with Wholesale Margins, which are traded.
24 This implies a coefficient of variation of $6.55 \%$.
unreasonably large employment increases in some sectors, tabulation of comparable magnitudes facilitates discussion. With the exception of the results reported in Table A1 in the Appendix, the experiments respect constraints on natural resource availability: labour is only diverted out of resource industries.

Results for "picking winners" - a policy that we would not recommend are reported in Table $A 1$ in the Appendix. ${ }^{25}$ These results generally accord with intuition, but also reveal some anomolies - perhaps a consequence of basing the analysis on the input-output structure of a single year. In particular, Petroleum Refining incurred a negative Other Operating Surplus in 1984, after receiving a subsidy of approximately half (48.97\%) of gross output and before an opportunity cost of capital was imposed. The refining industry is relatively risky and the single year of observation may not represent long-run prospects but other reasonable explanations include government policies. 26 In order to prevent the Petroleum Refining industry from dominating the sectoral results presented below, we restrict the analyses by holding employment in Petroleum Refining constant, i.e., $d \lambda_{j}=$ 0 if $\mathrm{j}=$ Petroleum Refining. ${ }^{27}$

We seek to identify regularities in the data and we prefer to incorporate the available industrial detall but base our interpretation on broad and systematic patterns. Accordingly, the results in Table 2 group the manufacturing and service industries into a manufacturing and service sector such that (with the exception of Petroleum Refining) relative employment proportions are held constant within this sector. These results

[^13]Table 2
Primary Industry Dependency and Diversification Saskatchewan, 1984

|  | $\mathrm{d} \mu$ | $\mathrm{d} \sigma$ | $\mathrm{d} \mu / \mathrm{d} \sigma$ |
| :---: | ---: | ---: | ---: |
| Agriculture into <br> Manufacturing \& Services <br> Mining into <br> Manufacturing \& Services <br> Oil \& Gas into <br> Manufacturing \& Services | -209.214 | -19.462 | 10.750 |

Note: In each case, 0.1\% of the provincial labour force is reallocated using the employment weights in Table 1. In all cases, employment in Petroleum Refining is held constant. See text.

Table 3
Trade Dependency and Diversification Saskatchewan, 1984

|  | $d \mu$ | $d \sigma$ | $d \mu / d \sigma$ |
| :--- | :---: | :---: | :---: |
| Self-sufficiency ( $\theta$ weights) | -85.642 | -12.047 | 7.109 |
| Resources ( $\theta$ weights) into ( |  |  |  |
| Manufacturing \& Services weights) | -84.444 | -11.879 | 7.108 |
| Manufacturing \& Services ( $\lambda$ weights) | -45.252 | -18.706 | 2.419 |

Note: In each case, $0.1 \%$ of the provincial labour force is reallocated, using the weights in Table 1 . In all cases, employment in Petroleum Refining is held constant. See text.
are illustrated in Figure 1.

Table 2 and Figure 1 reveal the effects of shifting labour from each of the major resource industries to the manufacturing and service sector. In each case, the result is stabilizing but, with the exception of Agriculture, income reducing. That Agriculture yields a below average return is not surprising today but was perhaps less apparent in 1984, a relatively good year in the light of recent experience. A significant specialization in resource exploitation dominates the Saskatchewan economy and it is hard to escape the conclusion that it has also exposed the province to additional risk.

The result of pursuing a policy of diversification in search of selfsufficiency, reported in Table 3 and illustrated in Figure 2, supports the view that exposure to world markets is risky. But enduring this risk yields a significant return: higher expected income. Since the pursuit of self-sufficiency is essentially a shift from resources - particularly Agriculture, Mining, and Oil and Gas - to manufacturing and services, the separate results for the resource industries suggest a partial explaination: activity is diverted from relatively risky, but on average, high return opportunities. However, we must also consider the choice of expanding industries.

In particular, the manufacturing and service sector, as defined by trade patterns, may be a relatively unattractive target for expansion. This question is pursued further in the remaining rows of Table 3 and also illustrated in Figure 2. In each case, activity is shifted from a resource sector, as defined by trade patterns, to the manufacturing and service sector. The destination industries in the manufacturing and service sector are defined first by the trade pattern and then by the pattern of existing activity. Shifting activity from trade-weighted resources to tradeweighted manufacturing and services closely reproduces the result for selfsufficiency.

Figure 1: Primary Industry Dependency and Diversification


Figure 2: Trade Patterns and Diversification


When the manufacturing and service sector is defined by trade patterns rather than employment patterns, the loss of expected income increases and - consistent with the view that exposure to world markets is risky - the gain in stability is reduced. We interpret these results as consistent with a pattern of employment in which Saskatchewan has specialized within the manufacturing and service sector in the direction of compartive advantage, albeit with an increase in risk. Stated differently, perhaps Saskatchewan people have revealed through the market allocation of activity a willingness to bear some additional risk in specialization and trade in return for a higher expected income.

## 5 Conclusions

In this paper, we have articulated and applied a tractable model of regional income creation under uncertainty. In particular, domestic and foreign varieties of commodities are distinguishable and the domestic varieties exchange at endogenous market clearing prices. Productivity shocks and foreign price shocks are explicitly modelled. The broadly sensible results lend weight to the view that regional production patterns reflect some specialization in the direction of comparative advantage and that this specialization exposes the region to additional risk.

The analysis is incomplete in a variety of ways, however. Adherence to an essentially linear (and log-linear) structure provides substantial algebraic and computational advantages but imposes strong assumptions on elasticities. Enriching the data base to account for government revenues and transfers is feasible; including capital and resource ownership patterns would be a desirable but more difficult undertaking. Incorporating labour mobility is perhaps a more immediate priority.

| Table A1 <br> "Picking Winners" <br> Saskatchewan, 1984 |  |  |  |
| :---: | :---: | :---: | :---: |
|  | d $\mu$ | d $\sigma$ | d $\mu / d \sigma$ |
| Resources |  |  |  |
| Agriculture | -15.358 | 5.763 | -2.665 |
| Fishing | 59.542 | -3.351 | -17.771 |
| Forestry | 82.340 | -1.816 | -45.351 |
| Mining | 212.046 | 18.022 | 11.766 |
| 011 \& Gas | 97.906 | 14.649 | 6.684 |
| Manufacturing |  |  |  |
| Food \& Beverages | -115.666 | -6. 427 | 17.997 |
| Rubber, Leather, \& Plastics | -63.829 | -3.336 | 19.136 |
| Textiles | -26.871 | -2.269 | 11.843 |
| Wood, Furniture, \& Paper | -30.808 | -2.267 | 13.580 |
| Printing \& Publishing | 7.743 | -2.203 | -3.515 |
| Primary \& Fabricated Metals | -40.394 | -2.806 | 14.394 |
| Transportation Equipment | -34.903 | -2.434 | 14.343 |
| Electrical Products | 0.138 | -2.207 | 0.063 |
| Non-metallic Minerals | -27.951 | -3.198 | 8.741 |
| Petroleum Refining | -1323.872 | -40.792 | 32.454 |
| Chemical Products | -144.358 | -4.374 | 33.003 |
| Miscellaneous Manafacturing | 3.195 | -2.090 | -1.528 |
| Services |  |  |  |
| Construction | -36.486 | -2.614 | 13.958 |
| Transportation \& Storage | -21.309 | -2.193 | 9.718 |
| Communications | -5.497 | -2.037 | 2.698 |
| Electrical Power \& Gas | -176.688 | -2.848 | 62.048 |
| Wholesale Trade | 21.644 | -2.143 | -10.100 |
| Retail Trade | 28.141 | -2.409 | -11.681 |
| Finance, Insurance, Real Estate | 1.474 | -1.945 | -0.758 |
| Commercial Services | 24.240 | -2.448 | -9.903 |
| Note: The labour force in the targetted industry is increased by $0.1 \%$ of the provincial labour force. Relative employment shares are preserved among the other industries. Industries for which expansion creates both higher and more stable income, i.e., "winners", are identified in italics. |  |  |  |
|  |  |  |  |
|  |  |  |  |
|  |  |  |  |
|  |  |  |  |

Table 12
Variance-Covariance Matrix of Commodity Prices Saskatchewan, 1984

| Commodity | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| 1 Grains | 0.03975 |  |  |  |  |  |  |  |  |
| 2 Other Agricultural Prod | 0.00292 | 0.00300 |  |  |  |  |  |  |  |
| 3 Forest Products | -0.00009 | 0.00121 | 0.00141 |  |  |  |  |  |  |
| 4 Fishing \& Trapping Prod | -0.00680 | 0.00243 | 0.00208 | 0.01218 |  |  |  |  |  |
| 5 Metal Concentrates | 0.00405 | 0.00138 | 0.00110 | 0.00174 | 0.00617 |  |  |  |  |
| 6 Non-metallic Minerals | 0.00979 | -0.00014 | -0.00076 | -0.00268 | 0.00605 | 0.02356 |  |  |  |
| 7 Mineral Fuels | 0.00908 | 0.00010 | -0.00029 | -0.00535 | 0.00135 | 0.00636 | 0.02275 |  |  |
| 8 Services to Mining | -0.00065 | -0.00046 | -0.00027 | -0.00058 | -0.00105 | -0.00052 | 0.00082 | 0.00054 |  |
| 9 Food Beverage Tobacco | 0.00194 | 0.00098 | 0.00049 | 0.00102 | 0.00074 | 0.00063 | -0.00074 | -0.00029 | 0.00059 |
| 10 Rubber Leather Plastic | 0.00191 | -0.00015 | -0.00013 | -0.00052 | 0.00051 | 0.00099 | -0.00060 | -0.00010 | 0.00006 |
| 11 Wood Prod \& Furniture | 0.00048 | -0.00012 | -0.00007 | 0.00015 | 0.00029 | 0.00003 | -0.00081 | -0.00013 | -0.00001 |
| 12 Paper \& Paper Prod | -0.00195 | 0.00198 | 0.00157 | 0.00436 | 0.00111 | -0.00240 | -0.00190 | -0.00037 | 0.00064 |
| 13 Metallic Prod | 0.00282 | -0.00039 | -0.00012 | -0.00007 | 0.00063 | 0.00216 | -0.00031 | -0.00005 | 0.00023 |
| 14 Mach Equip Autos Trucks | 0.00164 | 0.00010 | 0.00019 | 0.00034 | 0.00158 | 0.00223 | 0.00024 | -0.00018 | 0.00014 |
| 15 Electric \& Communic Prod | -0.00170 | -0.00026 | -0.00015 | -0.00033 | -0.00016 | -0.00012 | -0.00095 | 0.00007 | -0.00015 |
| 16 Petr Coal Chemical Prod | -0.00085 | -0.00023 | -0.00005 | 0.00012 | -0.00008 | -0.00001 | -0.00081 | 0.00005 | -0.00005 |
| 17 Misc Manufactures | 0.00585 | -0.00017 | -0.00077 | -0.00297 | 0.00005 | 0.00347 | 0.00819 | 0.00057 | -0.00026 |
| 18 Resid Construction | 0.00133 | -0.00028 | 0.00018 | -0.00079 | 0.00236 | 0.00263 | -0.00059 | -0.00066 | 0.00004 |
| 19 Non-res Construction | 0.00046 | 0.00041 | 0.00028 | 0.00141 | -0.00021 | -0.00099 | -0.00224 | -0.00021 | 0.00033 |
| 20 Repair Construction | 0.00127 | 0.00015 | -0.00006 | -0.00025 | -0.00012 | 0.00068 | -0.00037 | -0.00001 | 0.00015 |
| 21 Utilities | -0.00102 | -0.00020 | -0.00001 | 0.00018 | -0.00003 | -0.00050 | -0.00109 | 0.00004 | -0.00009 |
| 22 Trade Margins | -0.00262 | -0.00055 | -0.00031 | -0.00047 | -0.00083 | -0.00104 | -0.00031 | 0.00022 | -0.00040 |
| 23 Fin Ins Real Estate | -0.00090 | -0.00022 | -0.00004 | 0.00003 | -0.00019 | -0.00003 | -0.00098 | 0.00001 | -0.00005 |
| 24 Commun Bus Pers Services | -0.00311 | -0.00051 | -0.00004 | 0.00035 | -0.00065 | -0.00177 | -0.00090 | 0.00007 | -0.00021 |
| 25 Transportation Margins | -0.00289 | -0.00044 | 0.00002 | 0.00025 | -0.00065 | -0.00162 | -0.00175 | 0.00008 | -0.00019 |
| 26 Oper Suppl Trav Advert Prom | -0.00122 | -0.00055 | -0.00028 | -0.00090 | -0.00069 | -0.00039 | 0.00029 | 0.00026 | -0.00039 |
| 27 Non-comp \& Unall Imp \& Exp | -0.00115 | -0.00029 | -0.00010 | -0.00018 | -0.00043 | -0.00028 | -0.00093 | 0.00008 | -0.00009 |

Note: Commodity 6 is potash; see text.


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# ON THE BIAS OF MULTIPLIER ESTIMATES 

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#### Abstract

This note considers the matrix of multipliers when the underlying transactions table is stochastic. The usual assumptions of independency and unbiasedness of the individual errors are avoided. Under the condition that certain margins of the transactions table are known, the following result holds within each row and each column of the multiplier matrix. Either the biases are zero, or positive biases are canceled out by negative biases in the sense that their weighted average is zero. The results have a direct interpretation in connection with the $R A S$-updating procedure.


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## 1. Introduction

Within the context of a linear, multi-sector model, the matrix of multipliers (or Leontief inverse) plays an important role. It is extensively used to quantify the effects of economic policy and to calculate forecasts, both at a disaggregated level. In practical work, the matrix $M$ of multipliers is obtained from the matrix $A$ of input (or average expenditure) coefficients, as $M=(I-A)^{-1}$. In its turn, the matrix $A$ is derived from a transactions (or input-output) table $T$ by normalizing its columns. It is well known that the construction of a transactions table is exposed to many sources of measurement errors (see, for instance, Gerking, 1976). Given its crucial role, it is important to investigate how such errors affect the multiplier matrix.

In the discussion on the estimation of the multiplier matrix, the results by Simonovits (1975) have set the tone. ${ }^{1)}$ In that paper, it is assumed that the coefficients matrix $\underline{A}$ is stochastic with expected value (componentwise) $\mathcal{E}(\underline{A})=A$. When the coefficients $\underline{a}_{i j}$ are stochastically totally independent, it is shown that $\mathcal{E}(\underline{M})=\mathcal{E}\left[(I-\underline{A})^{-1}\right]>[I-\mathcal{E}(\underline{A})]^{-1}=(I-A)^{-1}=M{ }^{2)}$ When $A$ denotes the true, but unknown, coefficients matrix and $\underline{A}$ the observed, stochastic matrix, this result states that the mean of each observed multiplier exceeds the true multiplier. Several authors have shown this result to hold under various, different stochastic specifications (see Lahiri, 1983; Flam and Thorlund-Petersen, 1985; Lahiri and Satchell, 1985, 1986; West, 1986). ${ }^{3)}$ Clearly, this result has far-reaching consequences. For example, forecasts for next year's production at a disaggregated level $\left(x_{t+1}\right)$ are obtained by postmultiplying the multiplier matrix with the vector of predicted sectoral final demands $\left(f_{t+1}\right)$. This yields $\underline{x}_{t+1}=\underline{M} f_{t+1}$. But then, the forecasts are positively biased as follows from $\mathcal{E}\left(\underline{x}_{t+1}\right)=\mathcal{E}(\underline{M}) f_{t+1}>M f_{t+1}=x_{t+1}$.

In contrast to these results, a recent Monte Carlo study by Roland-Holst (1989) seems to indicate that multiplier estimates are unbiased. Where the above mentioned studies start from the coefficients matrix, Roland-Holst departs from an observed transactions table which is randomized.

In this note it is assumed that the coefficients matrix is derived from the transactions table. In other words, we adopt the practitioner's point of view. It is shown in section 2 that the usual stochastic specification of the coefficients matrix implies that the transactions table must be biased in a most remarkable way. In sections 3 and 4, therefore, the stochastic nature is
specified for the transactions table. It is shown that it is impossible that the traditional result, i.e. $\mathcal{E}(\underline{M})>M$, holds. It turns out that, under certain conditions, the weighted average of the elements in any row of the multiplier matrix even is unbiased. This result holds irrespective of the bias of the original error terms. Under slightly stronger conditions it is shown that the weighted average of the stochastic errors is zero within each row and column. The conditions state that certain margins of the transactions table are to be known exactly. This is precisely the type of information which is required for the application of the RAS-method for updating the coefficients matrix. In section 5 it is shown that the multiplier matrix, as obtained from an RASestimate of the coefficients matrix, exhibits correct weighted averages of its elements.

## 2. Stochastic coefficients matrices

In this section the assumption is adopted that the elements of the coefficients matrix are stochastically independent and unbiased. We examine the consequences of this assumption for the transactions table.

Consider a rectangular transactions table $T$ and distinguish $n$ production sectors, $k$ final demand categories and $l$ primary factors. $T$ denotes the true, but in some cases unknown, transactions table. Let $T$ be partitioned as follows.

$$
T=\left[\begin{array}{cc}
T_{n n} & T_{n k}  \tag{1}\\
T_{l n} & T_{l k}
\end{array}\right]
$$

The $n \times n$ matrix $T_{n n}$ gives the intermediate deliveries between the $n$ sectors, the $n \times k$ matrix $T_{n k}$ describes the final demands of the $k$ categories for the $n$ products, the $l \times n$ matrix $T_{l n}$ denotes the inputs of the $l$ primary factors into the $n$ production processes, the $l_{x} k$ matrix $T_{i k}$ measures the amounts of the $l$ primary factors used directly by the $k$ final demand categories. Let $e_{n}$ denote the column summation vector, consisting entirely of units, of length $n$. The vector $x_{n}$ of production levels (or outputs) is given as

$$
\begin{equation*}
x_{n}=T_{n m} e_{n}+T_{n k} e_{k} . \tag{2}
\end{equation*}
$$

The transactions table $T$ is called consistent if, for each of the $n$ sectors, the sum of the inputs equals the output. That is, $e_{n}^{\prime} T_{m n}+e_{i}^{\prime} T_{l n}=x_{n}^{\prime}$, where a prime is used to indicate transposition. The $n \times n$ matrix $A_{n n}$ of input coefficients is obtained as $A_{n n}=T_{n n} \hat{x}_{n}^{-1}$, where $\hat{x}_{n}$ denotes the diagonal matrix with the elements of the vector $x_{n}$ on its main diagonal. Similarly, $A_{l n}=$ $T_{l n} \hat{x}_{n}^{-1}$ denotes the $l \times n$ matrix of primary input coefficients. Using $T_{n n} e_{n}=$ $T_{n n} \hat{x}_{n}^{-1} x_{n}=A_{n n} x_{n}$, it follows from equation (2) that

$$
\begin{align*}
x_{n} & =A_{n n} x_{n}+T_{n k} e_{k} \\
& =\left(I-A_{n n}\right)^{-1} T_{n k} e_{k} \\
& =M T_{n k} e_{k}, \tag{3}
\end{align*}
$$

where $M=\left(I-A_{n n}\right)^{-1}$ denotes the matrix of multipliers.

Assumption 1. The matrices $\underline{A}_{n n}$ and $\underline{A}_{l n}$, and the vectrr $\underline{T}_{n k} e_{k}$ are stochastically independent and unbiased, i.e. $\mathcal{E}\left(\underline{A}_{n n}\right)=A_{n n}, \mathcal{E}\left(\underline{A}_{l n}\right)=A_{l n}$ and $\mathcal{E}\left(\underline{T}_{n k} \ell_{k}\right)=T_{n k} \ell_{k}$. The elements of the matrix $\underline{A}_{n n}$ are stochastically independent.

Theorem 1. Let $T_{n k} e_{k} \gg 0$ and $e_{i}^{\prime} A_{l n} \gg 0$. Then, under assumption $1, \mathcal{E}(\underline{T})$ is inconsistent if $T$ is consistent.

Proof. Define $\Omega=\mathcal{E}(\underline{M})-M>0$. Since $\underline{A}_{n n}$ and $\underline{T}_{n k} e_{k}$ are independent, also $\underline{M}=$ $\left(I-\underline{A}_{n n}\right)^{-1}$ and $\underline{T}_{n k} e_{k}$ are independent. Thus $\mathcal{E}\left(\underline{x}_{n}\right)=\mathcal{E}\left(\underline{M} \underline{T}_{n k} e_{k}\right)=\mathcal{E}(\underline{M}) \mathcal{E}\left(\underline{T}_{n k} e_{k}\right)=$ $(M+\Omega) T_{n k} e_{k}=x_{n}+\Omega T_{n k} e_{k}$. Next, $\underline{T}_{n n} e_{n}=\underline{A}_{n n} \underline{x}_{n}=\underline{x}_{n}-\underline{T}_{n k} e_{k}$ and $\mathcal{E}\left(\underline{T}_{n n} e_{n}\right)=$ $\mathcal{E}\left(\underline{x}_{n}\right)-\mathcal{E}\left(\underline{T}_{n k} e_{k}\right)=x_{n}+\Omega T_{n k} e_{k}-T_{n k} e_{k}=T_{n n} e_{n}+\Omega T_{n k} e_{k}$. Similarly, $\mathcal{E}\left(\underline{T}_{l n} e_{n}\right)=$ $\mathcal{E}\left(\underline{A}_{l n} \underline{x}_{n}\right)=\mathcal{E}\left(\underline{A}_{l n}\right) \mathcal{E}\left(\underline{x}_{n}\right)=A_{l n}\left(x_{n}+\Omega T_{n k} e_{k}\right)=T_{l n} e_{n}+A_{l n} \Omega T_{n k} e_{k}$. From this it follows that $\mathcal{E}\left(e_{n}^{\prime} \underline{T}_{n n} e_{n}+e_{l}^{\prime} \underline{T}_{I n} e_{n}\right)=e_{n}^{\prime} T_{n n} e_{n}+e_{i}^{\prime} T_{l n} e_{n}+\left(e_{n}^{\prime}+e_{l}^{\prime} A_{l n}\right) S T_{n k} e_{k}=e_{n}^{\prime}\left(x_{n}\right.$ $\left.+\Omega S T_{n k} e_{k}\right)+e_{i}^{\prime} A_{l n} \Omega T T_{n k} e_{k}=\mathcal{E}\left(\underline{x}_{n}^{\prime} e_{n}\right)+e_{i}^{\prime} A_{l n} \Omega T_{n k} e_{k}$. Since $\Omega>0, T_{n k} e_{k} \gg 0$ and $e_{l}^{\prime} A_{l n} \gg 0$, the scalar $e_{i}^{\prime} A_{l n} \Omega T_{n k} e_{k}>0$. Thus $\mathcal{E}\left(e_{n}^{\prime} T_{n n} e_{n}+e_{l}^{\prime} T_{l n} e_{n}\right)>\mathcal{E}\left(\underline{x}_{n}^{\prime} e_{n}\right)$. Consistency of $\mathcal{E}(\underline{T})$, however, requires that equality holds.

The conditions in this theorem state that for each product some of its output is used for final demand purposes and each production process uses some primary factor. The result can be interpreted within the context of simulation or estimation. In a simulation experiment, $T$ denotes an observed, consistent
transactions table. This table is used to derive the matrices $A_{n n}$ and $A_{l n}$, and the vector $T_{n k} e_{k}$. These are randomized so as to yield $\underline{A}_{n n}, \underline{A}_{i n}$ and $\underline{T}_{n k} e_{k}$, taking account of the conditions in assumption 1. Next $\underline{x}_{n}$ is obtained as $\underline{x}_{n}=$ $\left(I-\underline{A}_{n n}\right)^{-1} \underline{T}_{n k} e_{k}$ and the transactions table is constructed as $\underline{T}_{n n}=\underline{A}_{n n} \underline{\hat{x}}_{n}$ and $\underline{T}_{l n}=\underline{A}_{t_{n}} \hat{\hat{x}}_{n}$. Theorem 1 then asserts that $\mathcal{E}(\underline{T})$ is inconsistent. Moreover, it follows from its proof that $\underline{T}_{n n}$ and $\underline{T}_{l n}$ are biased, as $\mathcal{E}\left(\underline{T}_{n n} e_{n}\right)>T_{n n} e_{n}$ and $\mathcal{E}\left(T_{l n} e_{n}\right)>T_{l n} e_{n}$.

When the transactions table $T$ (resp. $\underline{T}$ ) is consistent, the coefficients in the matrices $A_{n n}$ and $A_{l n}$ (resp. $\underline{A}_{n n}$ and $\underline{A}_{1 n}$ ) sum to one within each column. That is, $e_{n}^{\prime} A_{n n}+e_{i}^{\prime} A_{l n}=e_{n}^{\prime}$ (resp. $e_{n}^{\prime} A_{n n}+e_{i}^{\prime} A_{l n}=e_{n}^{\prime}$ ) is necessary for $T$ (resp. $\underline{T}$ ) to be consistent. Obviously, if $\underline{T}$ is required to be consistent, the matrices $\underline{A}_{n n}$ and $\underline{A}_{l n}$ cannot be stochastically independent.

Within the context of estimation, $T$ denotes the true but unknown table. The observed table is used as an estimate of $T$ and $\underline{T}$ is the estimator of $T$. Suppose that any published transactions table is consistent, or, in other words, assume that $\underline{T}$ is consistent. Let the coefficients matrices be defined as $\underline{A}_{n n}=\underline{T}_{n n} \underline{\hat{x}}_{n}^{-1}$ and $\underline{A}_{l n}=\underline{T}_{l n} \underline{\hat{x}}_{n}^{-1}$. The following corollary states that the true, but unknown, transactions table $T$ cannot be consistent.

Corollary 1. Let $T_{n k} e_{k} \gg 0$ and $e_{i}^{i} A_{l n} \gg 0$. Then, under assumption $1, T$ is inconsistent if $\underline{T}$ is consistent.

Proof. Suppose, to the contrary, that $T$ is consistent. From the proof of theorem 1 it follows that $\mathcal{E}\left(e_{n}^{\prime} T_{n n} e_{n}+e_{l}^{\prime} \underline{T}_{l n} e_{n}\right)=\mathcal{E}\left(\underline{x}_{n}^{\prime} e_{n}\right)+e_{i}^{\prime} A_{l n} \Omega T_{n k} e_{k}$. Since $\underline{T}$ is consistent, $e_{n}^{\prime} \underline{T}_{n n}+e_{i}^{\prime} \underline{T}_{l n}=\underline{x}_{n}^{\prime}$, implying that $e_{i}^{\prime} A_{l n} \Omega T_{n k} e_{k}=0$, which is a contradiction.

So far we have implicitly assumed that each row of the matrix $T_{\text {ln }}$ corresponds to some primary input. The elements of the matrix $A_{l n}$ then measure, for any production sector, how much of each primary factor is used per unit of this sector's output. In many cases, however, the transactions table contains rows which may not be identified explicitly as primary factors. Such rows cover, for example, certain types of profits, taxes and subsidies. Its elements may be viewed as economic surpluses, and the use of input coefficients would therefore be questionable for these rows. In addition to this, some transactions tables explicitly record a row which is simply used to
generate consistency. Its elements may be regarded as statistical residuals.
Suppose that we distinguish, as before, l primary inputs. Further there is one row $\underline{r}_{n}^{\prime}$ of economic surpluses and/or statistical residuals. $\underline{x}_{n}$ satisfies $\underline{x}_{n}$ $=\underline{T}_{n n} e_{n}+\underline{T}_{n k} e_{k}$ and the $n$-element row vector $\underline{r}_{n}^{\prime}$ is obtained as $\underline{r}_{n}^{\prime}=\underline{x}_{n}^{\prime}-e_{n}^{\prime} \underline{T}_{n n}$
$-e_{i}^{\prime} T_{l n}$. Similarly, $x_{n}=T_{n n} e_{n}+T_{n k} e_{k}$ and $x_{n}^{\prime}=e_{n}^{\prime} T_{n n}+e_{i}^{\prime} T_{l n}-r_{n}^{\prime}$.

Corollary 2. Let $T_{n k} e_{k}>0$ and $e_{l}^{\prime} A_{l n} \gg 0$. Then, under assumption $1, \mathcal{E}\left(\underline{r}_{n}^{\prime} e_{n}\right)<$ $r_{n}^{\prime} e_{n}$.

Proof. $\mathcal{E}\left(\underline{r}_{n}^{\prime} e_{n}\right)=\mathcal{E}\left(\underline{x}_{n}^{\prime} e_{n}-e_{n}^{\prime} \underline{T}_{n m} e_{n}-e_{l}^{\prime} T_{l n} e_{n}\right)=x_{n}^{\prime} e_{n}-e_{n}^{\prime} T_{n n} e_{n}-e_{l}^{\prime} T_{l n} e_{n}-$ $e_{i}^{\prime} A_{l n} \Omega T_{n k} e_{k}=r_{n}^{\prime} e_{n}-e_{i}^{\prime} A_{l n} \Omega T_{n k} e_{k}$, from the proof of theorem 1 .

Again, this result may be interpreted from two different points of view. In a simulation study $T$ and $r_{n}^{\prime}$ correspond to the observed values. Using the procedure as sketched earlier, we find $\underline{T}$ and $\underline{r}_{n}^{\prime}$. It turns out that these are biased in a most unbalanced way. The total intermediate deliveries are overestimated in some sector, but they are nowhere underestimated, i.e. $\mathcal{E}\left(\underline{T}_{n n} e_{n}\right)>T_{n n} e_{n}$. The use of some primary input is overestimated, while for no primary input its use is underestimated, i.e. $\mathcal{E}\left(\underline{T}_{i n} e_{n}\right)>T_{i n} e_{n}$. The sum of the economic surpluses is underestimated, i.e. $\mathcal{E}\left(\underline{r}_{n}^{\prime} e_{n}\right)<r_{n}^{\prime} e_{n}$. In an estimation procedure, $\underline{T}$ and $\underline{r}_{n}^{\prime}$ are estimators of the true but unknown $T$ and $r_{n}^{\prime}$. The observed table is considered as an estimate.

## 3. The rows of the multiplier matrix

In the previous section the coefficients matrices were assumed to be stochastic. It was shown that assumption 1 leads to only positive biases in the rowsums of $\underline{T}_{n n}$ and $\underline{T}_{\underline{m}}$. This the more remarkable as information on aggregates is, in general, better than information on their components. "When we tabulate statistical data in the usual input-output form the row and column sums - total input and total output - are better known and more exact than the detail." (Bródy, 1970, p. 128).

Moreover, in practical situations, the coefficients matrices are computed from an observed transactions table. This yields $A_{n n}$ and $A_{l n}$ in a simulation experiment or one observation for the estimators $\underline{A}_{n n}$ and $\underline{A}_{l n}$ in an estimation procedure. Therefore it seems more appropriate to impose the stochastics at
the starting-point of the analysis. That is, on the transactions table instead of on the coefficients matrices.

Suppose that the transactions table is random. That is, $\underline{T}=T+\underline{\Delta}$, where the stochastic $(n+l) \times(n+k)$ matrix $\underline{\Delta}$ is partitioned according to (1).

$$
\underline{\Delta}=\left[\begin{array}{cc}
\underline{\Delta}_{n n} & \underline{\Delta}_{n k}  \tag{4}\\
\underline{\Delta}_{l n} & \underline{\Delta}_{l k}
\end{array}\right] .
$$

Note that in a simulation study $T$ denotes the observed transactions table and $\underline{T}$ the randomized table. For the purpose of estimation $T$ denotes the true but unkown table while we have one observation for its estimator $\underline{T}$.

Taking the outputs as the rowsums of the transactions table, we find

$$
\begin{equation*}
\underline{x}_{n}^{r}=\underline{T}_{n n} e_{n}+\underline{T}_{n k} e_{k}=x_{n}+\underline{\Delta}_{n n} e_{n}+\underline{\Delta}_{n k} e_{k} \tag{5}
\end{equation*}
$$

Taking the columnsums of the transactions table yields

$$
\begin{equation*}
\underline{x}_{n}^{c}=e_{n}^{\prime} \underline{I}_{n n}+e_{l}^{\prime} \underline{\underline{l}}_{l n}=x_{n}^{\prime}+e_{n}^{\prime} \underline{\Delta}_{n n}+e_{l}^{\prime} \underline{\Delta}_{l n} . \tag{6}
\end{equation*}
$$

$T$ is assumed to be consistent. When it is required that also $T$ is consistent, the vectors in (5) and (6) coincide. This yields $\underline{\Delta}_{n n} e_{n}+\underline{\Delta}_{n k} e_{k}=\underline{\Delta}_{n n}^{\prime} e_{n}+$ $\underline{\Delta}_{i n}^{\prime} e_{l}$, implying that the stochastic terms in $\underline{\Delta}$ cannot be independent. Although the assumption of the consistency of $\underline{T}$ is plausible for many practical cases, it appears not to be necessary for our results. Moreover, we would like to cover the case where, as sketched in the previous section, consistency is generated by an extra row (or, equivalently, column) vector. The only consequence of refraining from the assumption of a consistent $T$ is that, in defining $\underline{A}_{n n}=\underline{T}_{n n} \underline{\hat{x}}_{n}^{-1}$, it must be explicitly stated whether $\underline{x}_{n}^{r}$ or $\underline{x}_{n}^{c}$ is used.

Theorem 2. Let $\underline{A}_{n n}=\underline{T}_{n n}\left(\hat{x}_{n}^{r}\right)^{-1}$. If $\underline{\Delta}_{n k} e_{k}=0$ and $\mathcal{E}\left(\underline{x}_{n}^{r}\right)=x_{n}$, then $[\mathcal{E}(\underline{M}-M)] T_{n k} e_{k}=0$.

Proof. From (5) we have $\underline{x}_{n}^{r}=\underline{T}_{n n} e_{n}+\underline{T}_{n k} e_{k}=\underline{A}_{n n} \underline{x}_{n}^{r}+\underline{T}_{n k} e_{k}$ or $\left(I-\underline{A}_{n n}\right) \underline{x}_{n}^{r}=$ $\underline{T}_{n k} e_{k}$. Thus $\underline{x}_{n}^{r}=\underline{M} \underline{T}_{n k} e_{k}=\underline{M} T_{n k} e_{k}+\underline{M} \underline{\Delta}_{n k} e_{k}$. On the other hand $\underline{x}_{n}^{r}=x_{n}+\underline{\Delta}_{n n} e_{n}+$ $\underline{\Delta}_{n k} e_{k}=M T_{n k} e_{k}+\underline{\Delta}_{n n} e_{n}+\underline{\Delta}_{n k} e_{k}$ Rearranging terms yields

$$
\begin{equation*}
(\underline{M}-M) T_{n k} e_{k}=\underline{\Delta}_{n n} e_{n}+(I-\underline{M}) \underline{\Delta}_{n k} e_{k} . \tag{7}
\end{equation*}
$$

$\underline{\Delta}_{n k} e_{k}=0$ and $\mathcal{E}\left(\underline{x}_{n}^{r}\right)=x_{n}$ imply $\mathcal{E}\left(\underline{\Delta}_{n n} e_{n}\right)=0$ and the result follows from equation (7).

The elements of the matrix $\mathcal{E}(\underline{M}-M)$ denote the biases of the estimators of the multipliers. When $T_{n k} e_{k}$ is positive, theorem 2 asserts that, when some multiplier is underestimated, some other multiplier in the same row is overestimated. Moreover, in each row, the weighted average of the biases is zero. The weights are the same for each row and are given by the elements of the vector $T_{n k} e_{k}$. This result is applicable both for simulation experiments and for estimation purposes. Since $\underline{\Delta}_{n k} e_{k}$ is assumed to be zero, the vector $T_{n k} e_{k}$ of weights is known.

The condition $\Delta_{n k} e_{k}=0$ states that the errors in the $k$ final demand categories cancel each other out. The final demands themselves are not required to be known exactly, only the total final demand for each of the $n$ products is assumed to be free of errors. The condition $\mathcal{E}\left(\underline{x}_{n}^{r}\right)=x_{n}$ states that the first $n$ rowsums of the transactions table are unbiased. In conjunction with $\underline{\Delta}_{n k} e_{k}=0$ this condition implies that $\mathcal{E}\left(\underline{\Delta}_{n n} e_{n}\right)=0$, expressing that for each sector the sum of its intermediate deliveries is unbiased. Observe that the intermediate deliveries themselves are not required to be unbiased.

The following corollary ${ }^{4)}$ follows immediately from equation (7).

Corollary 3. Let $\underline{A}_{n n}=\underline{T}_{n n}\left(\underline{\hat{x}}_{n}^{r}\right)^{-1}$. If $\underline{\Delta}_{n n} e_{n}=\underline{\Delta}_{n k} e_{k}=0$, then $(\underline{M}-M) T_{n k} e_{k}=0$.

This implies that, when the margins $T_{n n} e_{n}$ and $T_{n k} e_{k}$ in the transactions table are known exactly, a negative error in $M$ can only occur when there is at least one positive error in the same row. Moreover, for each observation of the random table $\underline{T}$, the weighted average of the errors is always equal to zero, within each row.

The next theorem gives an alternative sufficient condition for the result in theorem 2. It may be used when the total final demands in each sector are not known exactly, i.e. $\Delta_{n k} e_{k} \neq 0$.

Theorem 3. Let $\underline{A}_{n n}=\underline{T}_{n n}\left(\underline{\hat{x}}_{n}^{c}\right)^{-1}$. If $\mathcal{E}\left(\underline{x}_{n}^{c}\right)=x_{n}$ and $\underline{\Delta}_{n n} e_{n}=\underline{\Delta}_{n n}^{\prime} e_{n}+\underline{\Delta}_{i n}^{\prime} e_{l}$, then $[\mathcal{E}(\underline{M}-M)] T_{n k} e_{k}=0$.

Proof. $\underline{x}_{n}^{r}=\underline{T}_{n n} e_{n}+\underline{T}_{n k} e_{k}=\underline{A}_{n n} \underline{x}_{n}^{c}+\underline{T}_{n k} e_{k}=\underline{A}_{n n}\left(x_{n}+\underline{\Delta}_{n n}^{\prime} e_{n}+\underline{U}_{i n}^{\prime} e_{l}\right)+T_{n k} e_{k}+$ $\underline{\Delta}_{n k} e_{k}$ and $\underline{x}_{n}^{r}=x_{n}+\underline{\Delta}_{n n} e_{n}+\underline{\Delta}_{n k} e_{k}$. Thus $\left(I-\underline{A}_{n n}\right) x_{n}=\underline{A}_{n n}\left(\underline{\Delta}_{n n}^{\prime} e_{n}+\underline{\Delta}_{i n}^{\prime} e_{l}\right)-\underline{\Delta}_{n n} e_{n}+$ $T_{n k} e_{k}$. Hence $x_{n}=\underline{M} T_{n k} e_{k}+\underline{M} \underline{A}_{n n}\left(\underline{\Delta}_{n n}^{\prime} e_{n}+\underline{\Delta}_{i n} e_{1}\right)-\underline{M} \underline{\Delta}_{n n} e_{n}$ and also $x_{n}=M T_{n k} e_{k}$. This yields $(\underline{M}-M) T_{n k} e_{k}=\underline{M} \underline{\Delta}_{n n} e_{n}-\underline{M}_{n n n}\left(\underline{\Delta}_{n n}^{\prime} e_{n}+\underline{\Delta}_{i n}^{\prime} e_{l}\right)$. Using $\underline{M}_{A_{n n}}=\underline{M}-I$ this gives $(\underline{M}-M) T_{n k} e_{k}=\underline{M}\left(\underline{\Delta}_{n n} e_{n}-\underline{\Delta}_{n n}^{\prime} e_{n}-\underline{\Delta}_{i n}^{\prime} e_{l}\right)+\left(\underline{\Delta}_{n n}^{\prime} e_{n}+\underline{\Delta}_{n}^{\prime} e_{l}\right)$. The condition $\mathcal{E}\left(\underline{x}_{n}^{c}\right)=$ $x_{n}$ implies $\mathcal{E}\left(\underline{\Delta}_{n n}^{\prime} e_{n}+\underline{\Delta}_{i n}^{\prime} e_{l}\right)=0$.

The condition of unbiased columnsums, i.e. $\mathcal{E}\left(\underline{x}_{n}^{c}\right)=x_{n}$, is equivalent to $\mathcal{E}\left(\underline{\Delta}_{n n} e_{n}\right)=0$ given that $\underline{\Delta}_{n n} e_{n}=\underline{\Delta}_{n n}^{\prime} e_{n}+\underline{\Delta}_{i n}^{\prime} e_{1}$. Note that the conditions in theorem 2 coincide with those of theorem 3 when $\underline{T}$ is consistent.

At first sight the condition $\underline{U}_{n n} e_{n}=\underline{\Delta}_{m n}^{\prime} e_{n}+\underline{\Delta}_{n n}^{\prime} e_{l}$ may seem to be rather restrictive. Thinking of the transactions table as a system of balanced accounting equations, however, it generally is true that one error causes another error. For example, any series of stochastic error rectangles in $T_{n n}$, in $T_{l n}$, or in $T_{n n}$ and $T_{\text {ln }}$ simultaneously, any series of stochastic symmetric error couples in $T_{n n}$, and any series of stochastic single diagonal errors satisfy the condition $\underline{\Delta}_{n n} e_{n}=\underline{\Delta}_{n n}^{\prime} e_{n}+\underline{\Delta}_{i n}^{\prime} e_{1}{ }^{5)}$

Similar to corollary 3, it follows from theorem 3 that $(\underline{M}-M) T_{n k} e_{k}=0$ if $\underline{\Delta}_{n n} e_{n}=\underline{\Delta}_{n n}^{\prime} e_{n}+\underline{\Delta}_{i_{n}} e_{1}=0$. Again, if some of the margins of the transactions table are known exactly, negative errors in any row of $M$ are canceled out by positive errors in the same row. The weighted average of the errors equals zero, which holds for each row.

## 4. The columns of the multiplier matrix

In this section, the elements of the multiplier matrix are analyzed columnwise. The results are similar to the one in corollary 3.

Theorem 4. Let $\underline{A}_{n n}=\underline{T}_{n n}\left(\underline{\hat{x}}_{n}^{r}\right)^{-1}$. If $\underline{\Delta}_{m n}^{\prime} e_{n}=\underline{\Delta}_{n n} e_{n}+\underline{\Delta}_{n k} e_{k}=0$, then $e_{i}^{\prime} T_{l n} \hat{x}_{n}^{-1}(\underline{M}-M)=0$.

Proof. $x_{n}^{\prime}=e_{n}^{\prime} T_{n n}+e_{l}^{\prime} T_{l n}=e_{n}^{\prime} A_{n n} \hat{x}_{n}+e_{l}^{\prime} T_{l n}$. Postmultiplication with $\hat{x}_{n}^{-1}$ gives $e_{n}^{\prime}\left(I-A_{n n}\right)=e_{i}^{\prime} T_{l n} \hat{x}_{n}^{-1}$ or $e_{n}^{\prime}=e_{l}^{\prime} T_{l n} \hat{x}_{n}^{-1} M$. By assumption, $0=e_{n}^{\prime} \underline{\Delta}_{n m}=e_{n}^{\prime} T_{n n}-$ $e_{n}^{\prime} T_{n n}=e_{n}^{\prime} \underline{A}_{n n} \underline{\hat{x}}_{n}^{r}-e_{n}^{\prime} A_{n n} \hat{x}_{n}$. Since $\underline{\Delta}_{n n} e_{n}+\underline{\Delta}_{n k} e_{k}=0$ it follows that $e_{n}^{\prime} \underline{A}_{n n}=$ $e_{n}^{\prime} A_{n n}$. Hence $e_{n}^{\prime}\left(I-\underline{A}_{n n}\right)=e_{n}^{\prime}\left(I-A_{n n}\right)=e_{l}^{\prime} T_{l n} \hat{x}_{n}^{-1}$. Thus also $e_{n}^{\prime}=e_{l}^{\prime} T_{l n} \hat{x}_{n}^{-1} \underline{M}$.

If it is assumed that each production process uses some primary input, the vector $e_{l}^{\prime} T_{l n} \hat{x}_{n}^{-1}$ is positive. Theorem 4 then asserts that within each column of the multiplier matrix at least one element is too large if some element is too small. Their weighted average however is correct. The conditions require that the first $n$ rowsums of the transactions table and the columnsums of $T_{n n}$ are known exactly. Note that since $\underline{\Delta}_{n n} e_{n}+\underline{\Delta}_{n k} e_{k}=0$, the outputs are exact, i.e. $\underline{x}_{n}^{r}=x_{n}$. Using the consistency of $T$, it follows that $e_{l}^{\prime} T_{l n}=x_{n}^{\prime}-e_{n}^{\prime} T_{n n}$ which is known exactly because $e_{n}^{\prime} \boldsymbol{\Delta}_{n n}=0$. Consequently, the vector of weights is known.

Theorem 5. Let $\underline{A}_{n n}=\underline{T}_{n n}\left(\underline{\hat{x}}_{n}^{c}\right)^{-1}$. If $e_{n}^{\prime} \underline{\Delta}_{n n}=e_{l}^{\prime} \underline{\Delta}_{i n}=0$, then $e_{i}^{\prime} T_{l n} \hat{x}_{n}^{-1}(\underline{M}-M)=0$.

Proof. Consider $e_{n}^{\prime}=e_{i}^{\prime} \underline{T}_{l n}\left(\underline{\hat{x}}_{n}^{c}\right)^{-1} \underline{M}$ and note that $\underline{x}_{n}^{c}=x_{n}$ from $e_{n}^{\prime} \underline{\Delta}_{n n}+e_{i \underline{\Delta_{l n}}}=$ 0 . Thus $e_{n}^{\prime}=e_{i}^{\prime}\left(T_{l n}+\underline{\Delta} \underline{l n}_{n}\right) \hat{x}_{n}^{-1} \underline{M}=e_{i}^{\prime} T_{l n} \hat{x}_{n}^{-1} \underline{M}$ which proves the result.

The conditions imply $\underline{x}_{n}^{c}=x_{n}$ and $e_{l}^{\prime} T_{l n}=e_{i}^{\prime} T_{l n}$. Hence, the vector $e_{l}^{\prime} T_{l n} \hat{x}_{n}^{-1}$ of weights is known, also in this case.

## 5. An application to the RAS-method

In the previous sections it was shown that the weighted average of the elements in each row (or each column) of the multiplier matrix is correct, provided that some of the margins in the transactions table are known exactly. This is precisely the type of information which is required by the $R A S$-method for updating an input-output matrix. This method generates an estimate for, say, this year's input-output matrix on the basis of last year's matrix, given this year's margins. Probably, this estimate will differ substantially from this year's true matrix. The same holds for the multiplier matrix as obtained from the estimated input-output matrix. However, it follows form our earlier results that the weighted averages in each row and column are correct.

First, a brief sketch of the $R A S$-method is given. ${ }^{6)}$ Consider last year's input-output matrix $A(0)$. Then the problem is to estimate this year's matrix $A(1)$, on the basis of the following prespecified information. $T_{n n}(1) e_{n}=u(1)$, $e_{n}^{\prime} T_{n n}(1)=v(1)^{\prime}$ and $x(1)$. The estimated matrix is required to satisfy the following equations

$$
\begin{equation*}
A(1) x(1)=u(1) \tag{8}
\end{equation*}
$$

$$
\begin{equation*}
e_{n}^{\prime} A(1) \hat{x}(1)=v(1)^{\prime} . \tag{9}
\end{equation*}
$$

The $R A S$-method estimates $A(1)$ iteratively, by adjusting $A(0)$ biproportionally. In the first step, define $r_{i}^{1}=u_{i}(1) / \sum_{j=1}^{n} a_{i j}(0) x_{j}(1)$ and $A^{1}$ $=\hat{r}^{1} A(0)$. In the first step, the estimate $A^{1}$ of $A(1)$ satisfies (8). In the second step, define $s_{j}^{2}=v_{j}(1) / \sum_{i=1}^{n} a_{i j}^{1} x_{j}(1)$ and $A^{2}=A^{1} \hat{s}^{2}=\hat{\tau}^{1} A(0) \hat{s}^{2}$. Note that this estimate of $A(1)$ satisfies (9). Next, $A^{3}=\hat{r}^{3} A^{2}, A^{4}=A^{3} \hat{s}^{4}$, et cetera.

Suppose that the rows are adjusted first. Then, for $t=1,2, \ldots$, define $r_{i}^{2 t-1}=u_{i}(1) / \sum_{j=1}^{n} a_{i j}^{2 t-2} x_{j}(1)$ and $A^{2 t-1}=\hat{r}^{2 t-1} A^{2 t-2}$ with $A^{0}=A(0)$. Next, define $s_{j}^{2 t}=v_{j}(1) / \sum_{i=1}^{n} a_{i j}^{2 t-1} x_{j}(1)$ and $A^{2 t}=A^{2 t-1} \hat{\mathcal{S}}^{2 t}$. It then follows that for $t=1,2, \ldots$,

$$
\begin{equation*}
A^{2 t}=\hat{r}^{2 t-1} \ldots \hat{r}^{3} \hat{r}^{1} A(0) \hat{s}^{2} \widehat{s}^{4} \ldots \hat{s}^{2 t} \tag{10}
\end{equation*}
$$

Similarly, when the columns are adjusted first, the estimate after $2 t$ steps becomes,

$$
\begin{equation*}
A^{2 t}=\hat{r}^{2 t} \ldots \hat{r}^{4} \hat{r}^{2} A(0) \hat{s}^{1} \hat{s}^{3} \ldots \hat{s}^{2 t-1} \tag{11}
\end{equation*}
$$

where the diagonal matrices are defined appropriately.
Both sequences of matrices $A^{2 t}$ are known to converge to the same limit under mild conditions. Let us write $\lim _{t+\infty} A^{2 t}=A_{(1)}^{R A S}$. Taking $A_{(1)}^{R A S}$ as the limit of $A^{2 t}$ in (10) yields $e_{n}^{\prime} A_{(1)}^{R A S} \hat{x}(1)=v(1)^{\prime}$. Using the expression in (11) gives $A_{(1)}^{R A S} x(1)=u(1)$.

Now we are able to apply the results from the previous sections. The true, but unknown, matrix is denoted by $A(1)$, its estimator by $A_{(1)}^{R A S}$. The estimator satisfies $A_{(1)}^{R A S} x(1)=u(1)$ and $e_{\boldsymbol{n}}^{\prime} A_{(1)}^{R A S} \hat{x}(1)=v(1)^{\prime}$. The vectors $\boldsymbol{u}(1), v(1)^{\prime}$ and $x(1)$ are given, but not necessarily all correct. The vectors $u(1)$ and $v(1)^{\prime}$ are related to the transactions table in the following way. $u(1)=T_{n n}(1) e_{n}$ and $v(1)^{\prime}=e_{n}^{\prime} T_{n n}(1)$. Define $M(1)=[I-A(1)]^{-1}$ and $M_{(1)}^{R A S}=\left[I-A_{(1)}^{R A S}\right]^{-1}$.

Corollary 4. If $u(1)$ and $x(1)$ are known correctly, $\left[M_{(1)}^{R A S}-M(1)\right][x(1)-u(1)]=0$.

Proof. $u(1)$ is exact implies $\underline{\Delta}_{n n} e_{n}=0, x(1)$ is exact implies $\underline{\Delta}_{n n} e_{n}+\underline{\Delta}_{n k} e_{k}=$ 0 , hence also $\underline{\Delta}_{n k} e_{k}=0$. Application of corollary 3 gives the result, with $T_{n k} e_{k}=[x(1)-u(1)]$.

Note that it is not necessary that $v(1)^{\prime}$ is known correctly. Even of the RASmethod is based on an erroneous row vector $v(1)^{\prime}$, the resulting multiplier matrix $M_{(1)}^{R A S}$ has correct weighted averages in each row. Thus, within every row, there are either no errors or both positive and negative errors. It is impossible that the errors have the same sign within a row.

Corollary 5. $\underline{x}(1)$ and $\underline{u}(1)$ are stochastic. If $\underline{x}(1)$ is unbiased and $\underline{x}(1)-\underline{u}(1)$ is deterministic and exactly known, then $\left[\mathcal{E}\left(M_{(1)}^{R A S}\right)-M(1)\right][x(1)-u(1)]=0$.

Proof. The condition that $\underline{x}(1)-\underline{u}(1)$ is deterministic and exactly known means that no errors are made in the total final demand for eac.a product, or that $\underline{\Delta}_{n k} e_{k}=0$. Theorem 2 then yields the result.

Finally, a sinilar result as in corollary 4 holds with respect to the columns of the multiplier matrix.

Corollary 6. If $v(1)^{\prime}$ and $x(1)$ are known correctly, $\left[x(1)^{\prime}-v(1)^{\prime}\right] \hat{x}(1)^{-1}\left[M_{(1)^{-}}^{\text {RAS }}\right.$ $M(1)]=0$.

Proof. $v(1)^{\prime}$ is exact implies $e_{n}^{\prime} \underline{\Delta}_{n n}=0$ and $x(1)$ is exact implies $\underline{\Delta}_{n n} e_{n}+$ $\underline{\Delta}_{n k} e_{k}=0$. Application of theorem 4 yields the result with $e_{i}^{\prime} T_{l n} \hat{x}_{n}^{-1}=\left[x(1)^{\prime}-\right.$ $\left.v(1)^{\prime}\right\} \hat{x}(1)^{-1}$.

## 6. Summary and conclusions

In this note, the matrix of multipliers was examined, given that the transactions table is stochastic. In contrast to the usual approach, the individual error terms did not need to be independent, nor unbiased. Instead it was assumed that certain margins of the transactions table are known exactly. Such assumption is frequently made in practical work when a transactions table is updated by means of the RAS-method. Under the given conditions, it was shown that any row and any column of the multiplier matrix
contains either positive as well as negative errors or no errors at all. The weighted average of the errors, in any row or column, is equal to zero. The weights are known and the same for each row and for each column. The same expressions, obviously, hold also for the biases in the elements of the multipier matrix. The same assertions were obtained for the biases within the rows of the multiplier matrix under the weaker condition that the sum of the intermediate deliveries in the transactions table is unbiased and that the total final demands are known exactly.

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## Footnotes

1) Early contributions are Evans (1954) and Quandt (1958, 1959).
2) For vectors and matrices we adopt the following notations and expressions. $x \geq 0$, nonnegative, means $x_{i} \geq 0$ for all $i ; x>0$, semipositive, means $x \geq$ 0 and $x \neq 0 ; x>0$, positive, means $x_{i}>0$ for all $i$.
3) See also Bullard and Sebald $(1977,1988)$ who focus on maximum error bounds.
4) A similar result was also obtained in Dietzenbacher (1988) for a series of deterministic error rectangles. See also Dietzenbacher (1990).
5) For an arbitrary matrix $B$ an eror rectangle is defined as $\underline{b}_{i j}=b_{i j}+\varepsilon^{r}$, $\underline{b}_{i k}$ $=b_{i k}-\varepsilon^{r}, \underline{b}_{g j}=b_{g j}-\varepsilon^{r}, \underline{b}_{g k}=b_{g k}+\varepsilon^{r}$, the symmetric error couple as $\underline{b}_{i j}=$ $b_{i j}+\varepsilon^{c}, b_{j i}=b_{j i}+\varepsilon^{c}$, and the single diagonal error as $\underline{b}_{i i}=b_{i i}+\varepsilon^{s}$.
6) For detailed discussions see, for instance, Bacharach (1970), Macgill (1977) or Miller and Blair (1985).

Modelling comodity balances

## Grahan Pyatt


#### Abstract

A path is traced in this paper from the representacion of commodity balances in a social accounting matrix Eramework to the modelling of such balances in the context of a computable general equilibrium. From the outset commodity balances are expressed here at market prices so that, in addition to the usual make and absorption matrices, a third matrix, referred to here as the marketing matrix, is needed in order to provide a complete description of commodity balances at the level of accounting. This description is then specialised by imposing the law of one price and assuming that activities produce bundles of products i.e. by assuming a general form of commodity technology.


A linear model of comodity balances is explored at the next stage and Stone's commodity technology model is shown to be a special case which can be derived via the reduced accounting framework to be obtained by eliminating the accounts for final commodities from the original matrix using the method of apportionment.

It is suggested that various problems which may arise in using Stone's model can either be ignored, on the grounds that the model remains a reasonable approximation, or the data base can be changed, possibly by improving the data themselves or by adopting an alternative (more detailed) classification of activities and products.

A third possibility is to drop the assumption of linearity and allow instead that the make matrix can be sensitive to relative product prices via technological possibilities for the transformation of products, and to introduce composite commodities as a way of allowing imports to compete with goods of domestic origin. In this way the commodity technology assumption can be accommodated within a general equilibrium approach and the modelling of commodity balances can be seen as a key component of a more general schema.

1. Why choose this topic ?
2. Commodity balances in a SAM framework
2.1 The SAM framework
2.2 The law of one price and commodity technology
2.3 The choice of classifications
3. Linear models
3.1 The general linear model
3.2 The Stone model
4. A more general model
4.1 Modelling the make matrix
4.2 Modelling competitive imports
4.3 The general syster revisited
```
The modelling of comodity balances has been the central concern of input-output analysis ever since Leontief first wrote about the subject more than fifty years ago. There have been various developments since, of course, and the contributions of Sir Richard Stone in formalising the distinction between what he called the commodity and industry technology models provides a benchmark for the developments which are to be discussed in this paper. These, then, are obvious reasons for choosing to discuss the modeling of comodity balances in this lecture. There are, however, some other considerations which suggest that the choice may be particularly appropriate at this time. A brief acknowledgement of these other reasons may therefore be useful by way of introduction to the substantive analysis.
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The work of Sir Richard Stone over many years in developing the conceptual framework of national income accounting is generally recognised. His collaboration with James Meade in producing national income estimates for the United Kingdom is well known, both on account of the clear line of development from this work to the first international standards for such accounts, as set out in OEEC [1952], and also because the intimate relationship between the architecture of the accounts, on the one hand, and the economics of Keynes, on the other, was evident for all to see, not only from the fact that Meade and Stone were working
```

```
directly for Keynes when undertaking their joint efforts,
but also because others, and notably Hicks, were quick to
see the importance of this essential connection between
theory and measurement.1/
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Similarly, the role of Stone as the chief architect of the subsequent revision of the 1952 OEEC standards, which were published as UNSO [1968], is equally well known. However, in contrast to the earlier version, the theoretical foundations of this later work are not so well understood or appreciated. Yet they can be traced quite easily; and they relate directly to input-output analysis and an enquiry into the economic development of the U.K. which Stone initiated in the late 1950's. This work was undertaken within the framework of what became known as the Cambridge Growth Project. So, while Keynes was asking in the early 1940's how Britain could pay for the war, Stone was asking, some twenty years later, how could the U.K. economy generate a better growth performance? He sought the answer in a model of the economy which was built around an input-output formulation of commodity balances which was driven in part, at least, by injections of consumer demand, formulated in such a way as to be sensitive to relative prices. These ingredients are to be found in Stone and Croft-Murray [1959], Stone [1960] and Cambridge, DAE [1962]. They represent, in parallel with the work of Johansen [1960], some early steps towards the development of what are now known as applied or computable general equilibrium models (CGEs).

The ticle of the 1960 volume cited above was 'Inputoutput and national accounts'. Within it, the distinction between commodity and industry technology is recognised, as is the link between prices and the structure of final demand. But it is not until we get to the 1962 volume that the industry and comodity technology models are identified as such, and the structure of transactions, with industries and commodities separately distinguished, is set out explicitly in a social accounting matrix (SAM) framework. It is at this point, therefore, that theory, data and issues have come together.

This detour into the history of ideas is useful for the light it casts on the dependence of developments in national accounting on applied analysis. For those who would consult the literature, it is clear that the 1968 SNA builds on the foundations laid in the Cambridge Growth Project, both in the treatment of commodity balances and the use of a matrix format as distinct from what are usually called T-accounts. These are perhaps the most important innovations in the 1968 revision. $\frac{2 /}{}$ As a development of them, it would be both logical and desirable if the latest round of revisions, now being finalised, were to carry the evolution a step further by seeking to develop the national accounts in line with developments over the past twentyfive years in computer technology and applied analysis. Unfortunately this is not happening and there is now a revisionist movement which harks back to the architecture of the SNA in its earlier, 1952 guise.

Two factors may have contributed to this revisionism.

| One is the rejection by most of to-day's economists of the |
| :---: |
| independence of relative prices and the structure of production |
| which is a feature of the earliest input-output models, |
| without realising that this simplification is by no means |
| essential or even important within a CGE model context. |
| The second consideration which can be mentioned here is |
| that input-output analysis as elucidated in UNSO [1968] |
| loses much of its earlier charm and simplicity. There is |
| now no longer one model of commodity balances but many, |
| depending on the choices made as between (i) industry versus |
| commodity technology; and (ii) market versus producer versus |
| basic prices, not to mention the treatment of imports as |
| complementary versus competitive or the option of expressing |
| commodity balances either as an equation of demand and supply |
| for commodities or as the demands on industries and the |
| supplies that match them. While the different concepts |
| which these choices reflect are relatively easy to understand, |
| the matrix algebra which is used in the 1968 SNA to elaborate |
| the alternatives is necessarily an acquired taste |

The development from early forms of input-output to today's CGE's is important for another reason also. Dramatic changes in Eastern Europe and the former Soviet Union imply that there is now a critical need for a new generation of economists in these countries who understand
how market economies work and the role of the price system within them. The historical experience of these countries is a system in which there is no immediate connection between prices and the allocation of resources or balance of payments. The modeling of commodity balances is central to an understanding of how that connection arises in market economics and therefore to the reorientation of economic policy which is now called for in those economies which previously were centrally planned.

### 2.1 The SAM approach

Table 1 sets out a social accounting matrix framework as a starting point for discussion. This recognises separate accounts for various activities and commodities, and an aggregate or consolidated account for all other transactions. By convention entries in a particular row are interpreted as a receipt for the account which corresponds to that row; entries in a particular column are outlays or expenditures. Because the matrix is a $S A M$, rows and columns are defined symetrically and the cotals of corresponding rows and column must be equal. Table 1 captures the basic idea of commodity balances in this sense that the total expenditure on a commodity (a row sum) must be equal to the total cost of supplying that commodity (a column sum).

Some alternative ways of classifying activities and commodities are to be discussed at a later stage in the argument. For now it may suffice to make three points which condition this discussion, the first of which is that the number of activities and commodities is arbitrary: the two do not have to be equal.

Secondly, an activity (or industry) is to be understood as a process, while a commodity is a good or service. It then follows from the fact that activities typically

Table 1

A basic social accounting matrix


Table 2
Tax onomy for classifying commodities


```
take place in particular locations - an office, factory
or warehouse, for example - that data on activities will
naturally relate to the establishment where the activity
is undertaken. Hence industries can be thought of as collec-
tions of establishments which have some particular common
denominator e.g. the collection of all dairy farms would
correspond to an activity (or industry) called 'dairy farming'.
```

The third particular feature of the present approach
is to distinguish between commodities according to their
source of supply and the market for which they are intended.
There are two main sources viz. domestic activities and
the rest of the world (which supplies imports); and two
destinations, namely domestic markets, and exports to the
rest of the world. As shown in Table 2 , to retain the richness
of detail that these differences imply requires an accounting
system which recognises two strata for commodities. These
are to be referred to here as basic and final respectively.
It also requires various groupings of commodities within
these strata, the determination of which has direct bearing
on the appropriate choice of commodity classifications.
These groupings can be explained in terms of the relationship
between Table l and Table 2.

To clarify the relationship between Table 1 and Table 2 we can start with domestic activities, the products of which are the primary commodities recognised in Table

```
1. Each activity may produce several products, both on
account of joint production and by-products in the technical
(engineering) sense, and because there is a distinction
to be made between products which are intended for sale
on domestic markets and those which are intended for export.
This does not mean that there is necessarily any physical
difference between the products intended for the different
markets. But incentives to supply the different markets
may be different. It is necessary therefore to make the
distinction if the possibility of modeling such differences
is to be retained.
```

The matrix $T_{a l}$ in Table 1 shows the value of each of the products produced by each activity. This matrix is known accordingly as the make matrix. It does not have to be square because the number of activities and commodities does not have to be equal. There are two main ways of modeling this matrix corresponding to Stone's distinction between industry and commodity technology. The difference between these will be explained subsequently. For the present it can be noted that the total revenue of an activity is obtained by summing along the appropriate row of the make matrix. Hence the vector of total revenues for all activities is the vector of row sums of the matrix $\mathrm{T}_{\mathrm{al}}$ i.e. the vector $y_{a}$.

```
    Basic commodities or products exist at their point
of origin in the domestic economy. Some are absorbed
```

```
into final use at this point, and these are recorded in
the vector of final demand for basic products, fl. Others
need to be markered for eventual sale, which means a process
of transformation involving eransport, distribution and
marketing costs. This process of transformation is accounted
for by the translation of basic into final commodities in
matrix T12, which shows the cost of a typical secondary
commodity as being the cost of the necessary primary product
plus its marketing costs. Hence matrix Tl2 can be referred
to as the marketing matrix. All subsistance production
and the output of 'do-it yourself' activities is included
in the vector fl. Hence the vector includes all the fish
which the fisherman retains from his catch for his own family's
consumption. The remainder of the catch is sold by the
fisherman for subsequent non-local distribution, and these
sales are recorded as elements of the marketing matrix,
T12.
```

```
    As indicated in Table 2, the rest of the world
provides an alternative source for commodities. The cost
of imports (valued cif) is recorded as an element of the
vector }\mp@subsup{v}{2}{}\mathrm{ , while the marketing costs of imported goods
provide additional non-zero entries in the matrix T12.
Similarly, any import duties which may be imposed on goods
are included here in the vector }\mp@subsup{v}{2}{}\mathrm{ , as are any other indirect
taxes which may be imposed on goods of either domestic or
foreign origin.
```

```
    It follows from this construction that final commod-
ities are goods available at point of sale and at market
prices. Their total cost or value is recorded accordingly
as the column sums of the accounts for final commodities,
i.e. as elements of the vector y2.
```

The revenue to meet these total costs is generated in the corresponding rows of Table l. It has two sources. One is the sale abroad of goods intended for export. This is foreign final demand, the value of which is recorded among the elements of the vector $f_{2}$. Otherwise, Table 1 shows that final commodities are sold on domestic markets as final goods or as raw material inputs into industries. What these alternatives amount to can be explained with reference to Table 2.
As indicated in Table 2 , both imported commodities
and domestic commodities destined for the domestic market
can each be split into two groups. Some of the imports
are goods which have no domestically produced substitute.
These are known as complementary imports. And some of the
goods produced for the domestic market have no imported
substitute. These are known as non-traded goods. All other
final commodities originate as competitive imports or as
domestic products which are destined to compete with imports
in final markets. in final markets.

```
    For purposes of analysis, these distinctions between
different types of final commodities are important, since,
for each category, the way in which demand might be modelled
can be quite different. The precise form need not concern
us immediately while the general point is quite obvious
in relation to complementary imports, exports and non-traded
goods, which are sold on the domestic market either as a
part of the final demand for final commodities, f2, or as
raw material inputs into industry, which are recorded in
the matrix T Ta. However, the way forward is less apparent
in relation to competitive imports and the domestic products
which compete with them. When these competing commodities
from alternative sources are perfect substitutes then the
choice is relatively simple : it can be expected that the
market will choose the cheaper commodity. But when the
two sources of supply deliver imperfect substitutes, then
imported commodities and domestic goods are likely to be
used in some combination. To allow for this possibility
calls for an elaboration of the analysis which is deferred
until section 4.2. Meanwhile, it can be noted that matrix
T2a}will be referred to here as the absorption matrix sinc
it shows the details of how final commodities are used as
intermediate inputs into production activities.
To conclude this part of the discussion, three final points can be made. First, it is evident from Table 1 that the structural interdependence of production and
```

commodity balances is captured by the three matrices $T a l$, $T_{12}$ and $T_{2 a} i . e . b y$ the make, marketing and absorption matrices. Formats in which the marketing matrix is supressed are, of course, possible. But, as will be argued subsequently, they are also less interesting.

Secondly, it can be noted that the column sums of the absorbtion matrice $T_{2 a}$ give the total intermediate costs of each activity. The difference between these totals and total revenue is therefore value added, and this is recorded for each activity as an element of the vector $\mathrm{v}_{\mathrm{a}}$.

Finally, because Table 1 is a SAM, the equivalence of row and column totals for each activity and commodity account implies that total receipts and total outlays for the remaining aggregate or residual account must also be equal. There is therefore no need to discuss the balance of this account explicitly.

### 2.2 The law of one price and commodity technology

```
Economics takes over from accuntancy when restrictions are imposed on the structure of the SAM and its various entries. The starting point for this process in the present case is known as the law of one price, which states that all transactions involving a given commodity take place at the same price. The extent to which this law is approximated in practice must depend on the design and detail of the classifications adopted for disaggregating commodities. For example, if a manufacturer can obtain a significantly better price for his product on the domestic market than he can abroad, then the system of classification of products should recognise this distinction. And if the law holds, then the transactions \(T_{i j}, f_{i}\) and \(y_{i}\) in Table \(l\) can be rewritten as
```

$$
\begin{equation*}
T_{12}=\hat{P_{1}} Q_{12} \text { and } T_{2 a}=\hat{P_{2}} Q_{2 a} ; \tag{1}
\end{equation*}
$$

and

$$
\begin{equation*}
y_{i}=p_{i} q_{i} ; f_{i}=p_{i} \phi_{i} \text { for } i=1 \text { and } 2 \tag{2}
\end{equation*}
$$

```
where P1 and P2 are vectors of prices for basic and final
commodities and }\mp@subsup{\phi}{i}{}\mathrm{ for i = 1 and 2 is the quantity of final
demand for each of these two types of commodities. Similarly,
qi}\mathrm{ is the total amount of commodity i bought and sold
in the economy and it follows that
```

$$
\begin{align*}
& q_{1}=Q_{12} i+\phi_{1} ; \text { and }  \tag{3}\\
& q_{2}=Q_{2 a} i+\phi_{2} \tag{4}
\end{align*}
$$

```
where i is now a unit vector comformable with the matrix
it multiplies. Hence the quantities of domestic products
sold as inputs into final commodities is ( Q12 i; and Q Q a i
is the quantity vector of aggregate intermediate inputs
Of final commodities for all activities.
```

The substitutions implied by the law of one price are represented in $T a b l e$, along with an alternative treatment of the vectors $\mathrm{y}_{\mathrm{a}}, \mathrm{v}_{\mathrm{a}}$ and $\mathrm{v}_{2}$ as

$$
\begin{equation*}
\mathrm{y}_{\mathrm{a}}=\hat{\mathrm{P}}_{\mathrm{a}} \mathrm{q}_{\mathrm{a}} ; \mathrm{v}_{\mathrm{a}}=\hat{\pi}_{\mathrm{a}} \mathrm{q}_{\mathrm{a}} ; \text { and } \mathrm{v}_{2}=\hat{\pi}_{2} \mathrm{q}_{2} \tag{5}
\end{equation*}
$$

Hence it is assumed that a measure (index) of output can be formed for each activity and that $q_{a}$ is the resulting vector of activity outputs. Given total revenues, $y_{a}$ and the value added vector, $v_{a}$, it follows that $P_{a}$ and $\pi_{a}$ are vectors of gross and net output prices respectively, while $T_{2}$ is a vector of import costs and indirect taxes per unit of each final commodity which is supplied to the economy.

Table 3 is now completed by expressing the make matrix $\mathrm{T}_{\text {al }}$ as

$$
\begin{equation*}
T_{a l}=Q_{a l}^{\star} \hat{\mathrm{P}_{1}} \tag{6}
\end{equation*}
$$

Table 3
SAM structure assuming commodity technology and the law of our price


Table 4
The balance equations implied by Table 3



#### Abstract

which implies that the elements of the matrix $Q^{\star}$ al are the quantities of each product produced by each activity.


```
    Equation (6) introduces Stone's commodity technology
assumption in a generalised form. It contrasts with the
corresponding industry technology assumption which requires
equation (6) to be replaced by
```

$$
\begin{equation*}
\mathrm{T}_{\mathrm{al}}=\hat{\mathrm{P}}_{\mathrm{a}} \mathrm{Q}_{\mathrm{al}} \tag{7}
\end{equation*}
$$

Under this alternative, an element of $Q_{a l}$ is a fraction of the physical output of an activity which contributes to the supply of a particular product. In so far as the outputs of activities are combinations of products, the commodity technology assumption is evidently more attractive than the industry alternative.

Some implications of these various assumptions are brought together in Table 4 , which shows a set of seven equations. These are all derived directly from Table 3 as the necessary conditions for the matrix entries to add up by rows and columns to the totals shown. In particular it can be noted that equations (3) and (4) re-emerge here as the row equations for the commodity accounts.

The development from Table 4 to Table 5 involves two innovations. The first is to replace the matrices $Q_{12}$, and $Q_{2 a}$ by expressions of the form

$$
\begin{equation*}
\mathrm{Q}_{12}=\mathrm{L}_{12} \hat{\mathrm{q}}_{2} \text { and } \mathrm{Q}_{2 \mathrm{a}}=\mathrm{L}_{2 \mathrm{a}} \hat{\mathrm{q}}_{\mathrm{a}} \tag{8}
\end{equation*}
$$

Table 5
An elaboration of the balance equations

| Account | Row equation | Column equation |
| ---: | :--- | :--- |
| Activities | $p_{a}=S_{1 a}^{\prime} p_{1}$ | $P_{a}^{\prime}=p_{2}^{\prime} L_{2 a}+\pi_{a}^{\prime}$ |
| Commodities Basic | $q_{1}=L_{12} q_{2}+\phi_{1}$ | $q_{1}^{\prime}=q_{a}^{\prime} S_{1 a}^{\prime}$ |
| Final | $q_{2}=L_{2 a} q_{a}+\phi_{2}$ | $p_{2}^{\prime}=p_{1}^{\prime} L_{12}+\pi_{2}^{\prime}$ |
| All other accounts | $p_{1}^{\prime} \phi_{1}+p_{2}^{\prime} \phi_{2}=\pi_{a}^{\prime} q_{a}+\pi_{2}^{\prime} \cdot q_{2}$ |  |

Table 6
Table I after apportioning out the final commodity accounts


The second is to replace $Q^{*}$ al by

$$
\begin{equation*}
Q_{a l}^{*}=\hat{q}_{a} S_{1 a}^{\prime} \tag{9}
\end{equation*}
$$

The implication of equation (8) is that the elements of the matrices $L_{i j}$ are relative quantities of $i$ per unit of $j$. The elements of $L_{2 a}$ are, therefore, quantities of final commodities absorbed per unit of output by each activity, So $L_{2 a}$ is an absorbtion coefficient matrix. Similarly, $\mathrm{L}_{12}$ is a marketing coefficient matrix the columns of which show the input of each basic product which is needed to produce one unit of a particular final product. The implication of (9) is that the elements of a typical column of $S_{1 a}$ are the quantities of each product produced by a particular activity per unit of output. Hence $S_{l a}$ is a commodity technology make matrix in coefficient form.

It should be emphasised at this point that the equations set out in Table 5 are virtual identities in the sense that they are a development of the accounting constraints implied by Table 3 which depends only on the assumption that price vectors $P_{a}, P_{1}$ and $P_{2}$ exist and that the law of one price maintains. These are the only conditions necessary for the values in Table 1 to be expressed as in Table 3 as the product of prices and corresponding quantities.

```
    It can also be noted that the equations in Table
5 are a very general form of CGE model involving che variables
\mp@subsup{p}{a}{}},\mp@subsup{q}{a}{},\mp@subsup{\pi}{a}{},\mp@subsup{\pi}{2}{},\mp@subsup{S}{1a}{},\mp@subsup{L}{2a}{},\mp@subsup{L}{12}{}\mathrm{ and }\mp@subsup{P}{i}{},\mp@subsup{q}{i}{}\mathrm{ and
\varnothing
be obtained by recognising some further interdependencies
between these variables or by treating them as predetermined.
Particular examples of such developments are to be discussed
in subsequent sections of this paper. But, before coming
to them, it may be useful at this stage to comment on the
choice of classifications to be adopted for activities and
commodities.
```


### 2.3 The choice of classifications


#### Abstract

The preceding discussion of the design of a social accounting matrix to capture the details of commodity balances has some evident implications for the way in which commodities might be classified and the extent to which disaggregation is desirable


```
It can, of course, be argued that a highly detailed disaggregation is desirable, and the more detail the better. However, while this is certainly the case if the main application is market research for particular commodities, the quest for more detail is generally misguided if the primary concern is to assist in the design of a suitable macro-economic policy. In this latter context the previous discussion suggests three guidelines for the choice of commodity groupings, the first of which is the need to recognise two levels of commodities. A second concern must then be to achieve a disaggregation of commodities which maps into the groupings which need to be recognised within and between these strata - subsistance output, exports, inputs into marketing (transport, distribution), other non-traded goods, complementary imports, competitive imports and domestic products. Further disaggregation within these groupings can then be guided by the law of one price, which suggests that major differences in production technology may be important e.g. the distinction among nontraded goods between government services, construction and public utilities may be important because their production is intensive in labour, working capital and physical capital
```

```
respectively, so that different considerations may drive
movements in their costs. Similarly, it may be important
to disaggregate the domestic market for final goods by
location e.g. rural versus urban, or to recognise different
ways in which production is organised as between, say, commercial
banking and the curb market, or plantation agriculture as
opposed to smallholdings or share cropping. Much of the
art of model building depends on the way in which classifi-
cations are chosen in relation to issues, available data
and size of the model.
```

From these considerations it follows that an automatic
rule for fixing classifications is not a good idea. Yet
such a rule is often invoked to determine the classification
of activities, with the result that much subsequent analysis
is far less useful than it might otherwise be.

The rule which is usually invoked for classifying activities is the principle product rule. Recalling that data on activities typically relate to an establishment, the principle product rule assumes a classification of products (basic comodities) and allocates each establishment uniquely to a particular industry or activity by defining an industry as the set of establishments which have a particular product as their most important source of revenue. One effect of this somewhat circular approach is to yield a system in which the number of activities and products is equal, so that the resulting make matrix $T_{l a}$ is square.

```
A second consequence is that the largest elements of Tla
will tend to lie on the diagonal because sales of its principle
product will dominate for every establishment and, therefore,
for each industry or activity. And, as a result of this,
there is actually very little new information contained
in the make matrix when the principle product approach is
used to group establishments i.e. the off-diagonal entries
are relatively small.
```

There is in fact no need for the make matrix to be square: and the information content of this matrix is greatly enhanced when activities are classified according to their ownership, form of organisation, location and/or technology. These are the ways of classifying activities which are most useful for analytic purposes. Similarly, the most useful grouping of commodities is one which recognises the distinctions which arise between and within the different strata of commodities and the need to approximate the law of one price. The make matrix should then be a mapping from the classifiction of activities into that of commodities which recognises these concerns. As such, it is unlikely to be diagonal or even square.

## 3. Linear Models

### 3.1 The general linear model

A linear model of commodity balances can be obtained
from the general system set out in Table 5 by as suming that
the matrices $S_{l a}$, and $L_{12}, L_{2 a}$ are fixed independent of
all prices and quantities. These fixed matrices can be
denoted $\bar{S}_{1 a}, \overline{\mathrm{~L}}_{12}$ and $\overline{\mathrm{L}}_{2 a}$.

The assumption that these three matrices are fixed independent of quantities and prices implies that technology can be described by a set of fixed coefficient matrices. More specifically, the assumption that $L_{2 a}$ and $S_{1 a}$ are fixed coefficient matrices implies that raw material requirements are proportional to the level of activity in each industry, and that the products of each industry are generated in fixed proportions, independent both of prices and the level of activity. Similarly, the notion that $\mathrm{L}_{12}$ is fixed implies that marketing inputs must be proportional to sales volumes for every commodity. These are strong assumptions and, in particular, the assumption that $L_{2}$ is fixed independent of prices is not easily reconciled with the existence of competitive imports. The implication, therefore, is that all imports must be complementary if the assumptions of the linear model are to be maintained. The standard linear model does not, therefore, provide a useful framework within which to analyse the implications
of competition between domestically produced and imported goods.


#### Abstract

To calibrate the linear model it is useful to assume that the starting point for analysis is a SAM such as Table 1 for some base period, and to adopt the convention that all quantities are defined in units such that all prices are one in the base period.


Now it follows from equations (1), (2) and (8) that

$$
\begin{equation*}
\mathrm{T}_{12} \hat{\mathrm{y}}_{2}-1=\hat{\mathrm{P}}_{1} \mathrm{~L}_{12} \hat{\mathrm{P}}_{2}-1 \tag{10}
\end{equation*}
$$

so that, if $L_{12}$ is a matrix of fixed coefficients, $\bar{L}_{12}$, then the convention that all prices are one in the base period implies that

$$
\begin{equation*}
\left(\mathrm{T}_{12} \hat{\mathrm{y}}_{2}^{-1}\right)^{0}=\overline{\mathrm{L}}_{12} \tag{11}
\end{equation*}
$$

where the left-hand side of (ll) is the matrix on the lefthand side of (10) evaluated from base period data. Similarly, it follows from Table 1 that

$$
\begin{equation*}
i^{\prime} T_{12}=y^{\prime} 2-v^{\prime}{ }_{2} \tag{12}
\end{equation*}
$$

so that, from (5),

$$
\begin{equation*}
i^{\prime} T_{12} \hat{y}_{2}^{-1}=i^{\prime}-\pi_{2}^{\prime} \hat{\mathrm{P}}_{2}-1 \tag{13}
\end{equation*}
$$

Hence, from (ll), the convention implies that

$$
\begin{equation*}
i^{\prime} \vec{L}_{12}=\left(i-\pi_{2}\right)^{\prime} \tag{14}
\end{equation*}
$$

Using similar arguments, the matrix $\bar{L}_{2 a}$ can
be estimated as

$$
\begin{equation*}
\bar{L}_{2 a}=\left(T_{2 a} \hat{y}_{a}-1\right)^{0} \tag{15}
\end{equation*}
$$

and it will then follow that

$$
\begin{equation*}
i^{\prime} \bar{L}_{2 a}=\left(i-\pi_{a}\right)^{\prime} \tag{16}
\end{equation*}
$$

Similarly, $S_{1 a}$ can be estimated as

$$
\begin{equation*}
\bar{s}_{1 a}^{\prime}=\left(\hat{y}_{a}-1 T_{a l}\right)^{0} \tag{17}
\end{equation*}
$$

and it then follows that

$$
\begin{equation*}
\vec{S}_{1 a}{ }^{\prime} i=i \tag{18}
\end{equation*}
$$

An implication of this last result which is useful for future reference is that

$$
\begin{equation*}
i^{\prime} \bar{S}_{1 a^{\prime}}^{-1}=i^{\prime} \tag{19}
\end{equation*}
$$

The solution of the linear model is straightforward or more complicated, depending on what one means by a solution.

To clarify this remark, it can be noted that, from Table 5, when $S_{1 a}, L_{12}$ and $L_{2 a}$ are fixed coefficient matrices, then

$$
\left[\begin{array}{l}
q_{1}  \tag{20}\\
q_{2}
\end{array}\right]=\left[\begin{array}{ll}
\bar{s}_{1 a} & 0 \\
\bar{L}_{2 a} & 1
\end{array}\right] \cdot\left[\begin{array}{l}
q_{a} \\
q_{2}
\end{array}\right]
$$

and

$$
\begin{equation*}
\phi_{1}=q_{1}-\bar{L}_{12} q_{2} \tag{21}
\end{equation*}
$$

Hence, for given $q_{a}$ and $\phi_{2}$, the values of $q_{1}$ and $q_{2}$ can be determined from equation (20) and $\phi_{1}$ can then be determined from (21). It is therefore a simple matter to solve for $q_{1}, q_{2}$ and $\phi_{1}$ as functions of $q_{a}$ and $\phi_{2}$. In particular it can be noted that (20) and (21) imply that

$$
\begin{equation*}
\left(\overline{\mathrm{S}}_{1 \mathrm{a}}-\overline{\mathrm{L}}_{12} \overline{\mathrm{~L}}_{2 a}\right) \mathrm{q}_{\mathrm{a}}=\phi_{1}+\overline{\mathrm{L}}_{12} \phi_{2} \tag{22}
\end{equation*}
$$

Similarly, in relation to prices, it follows from Table 5 that when $S_{1 a}, L_{12}$ and $L_{2 a}$ are fixed,

$$
\left[\begin{array}{l}
\mathrm{P}_{\mathrm{a}}  \tag{23}\\
\mathrm{P}_{2}
\end{array}\right]=\left[\begin{array}{ll}
\mathrm{S}_{1 \mathrm{a}^{\prime}} & 0 \\
\mathrm{~L}_{12}{ }^{\prime} & \mathrm{I}
\end{array}\right] \cdot\left[\begin{array}{l}
\mathrm{P}_{1} \\
\mathrm{~T}_{2}
\end{array}\right]
$$

and

$$
\begin{equation*}
\pi_{a}=P_{a}-\bar{L}_{2 a^{\prime}} P_{2} \tag{24}
\end{equation*}
$$

```
with the implication that
```

$$
\begin{equation*}
\left(\bar{s}_{1 a}-\bar{L}_{12} \bar{L}_{2 a}\right)^{\prime}{ }_{P 1}=\pi_{a}-\bar{L}_{2 a} \pi_{2} \tag{25}
\end{equation*}
$$

Hence, for given $P_{1}$ and $\pi_{2}$, it is always possible to solve for $P_{a}$ and $P_{2}$ from (23) and, therefore, to determine the vector $\pi_{a}$ via (24). Thus $P_{a}, P_{2}$ and $\pi_{a}$ are readily determined as functions of $P_{1}$ and $\pi_{2}$.

In the above sense the linear model is easily solved. The model involves $3\left(a+n_{1}\right)+4 n_{2}$ variables, where a is the number of activities, and $n_{1}$ and $n_{2}$ are the numbers of primary and final comodities respectively. The variables are $\boldsymbol{\pi}_{a}, P_{a}$ and $q_{a} ; P_{1}, \phi_{1}$ and $q_{1}$; and $\pi_{2}, P_{2}$ and $9_{2}$. With the matrices $L_{12}, L_{2 a}$ and $S_{1 a}$ fixed, the balance equations in Table 5 define $2\left(a+n_{1}+n_{2}\right)$ independent linear equations in these variables, shown here as equations (20), (21), (23) and (24), which leaves $a+n_{1}+2 n_{2}$ degrees of freedom in the system. More specifically, the system allows for the $2\left(a+n_{1}+n_{2}\right)$ variables $\pi_{a}, P_{a}, q_{1}, \phi_{1}, P_{2}$ and $q_{2}$ to be determined as functions of the $a+n_{1}+2 n_{2}$ variables $q_{a}, P_{1}, \varnothing_{2}$ and $\boldsymbol{T}_{2}$.

```
    A necessary feature of such solutions is that
the balance equation for the 'all other' account in Table
5 will be satisfied, as can be verified by substituting
the solution values given by equations (20), (21), (23)
and (24) in the balance equation.
```


#### Abstract

The sense in which the solution of the linear model is more complicated follows from the fact that the above analysis does not imply that $q_{a}, q_{1}$ and $q_{2}$ can necessarily be determined uniquely when $\phi_{1}$ and $\phi_{2}$ are known. For this to be possible, it must be possible to solve equation (22) for $q_{a}$ as a function of $\phi_{1}$ and $\phi_{2}$ which, in turn implies that the matrix $\left(\bar{S}_{1 a}-\bar{L}_{12} \bar{L}_{2 a}\right)$ can be inverted i.e. that $$
\begin{equation*} \left(\bar{S}_{1 a}-\bar{L}_{12} \bar{L}_{2 a}\right)^{-1} \text { exists } \tag{26} \end{equation*}
$$

Similarly, from (25) it is evident that this same condition must be satisfied if it is to be possible to determine prices $P_{a}, P_{1}$ and $P_{2}$ as functions of $\pi_{a}$ and $\pi_{2}$.

Whether it is desirable to be able to determine quantities $q_{i}$ as a function of $\phi_{1}$ and $\phi_{2}$, or prices $P_{i}$ as a function of $\pi_{a}$ and $\pi_{2}$ is debatable since it is not an obvious characterisation of the way in which an economy actually works. However, it is the way in which the early input-output models assumed that economies work. Accordingly, there has been a particular interest historically in the condition (26).


### 3.2 The Stone model

```
Two specialisations of the general linear model
are needed in order to arrive at Stone's model of commodity
balances. The first of these is to eliminate the accounts
for final commodities from the SAM presented as Table 1.
The second is to specify a set of particular conditions
under which the resulting model will have a solution in
the sense that the conditon (26) will be satisfied.
```

The first of these steps can be achieved by a technique referred to in Pyatt [1989] as apportionment. This manipulation of a SAM is essentially similar to the method of double deflation proposed in Leontief [1967] as a way of improving the comparability of input-output tables. In the present context, the technique involves the attribution of the costs of generating final commodities to those who buy final commodities, with the amounts attributed being proportional to the amounts that each purchaser spends. In this sense the cost of the constituent elements of each final commodity are apportioned among the buyers of each comodity. And the result is to replace the SAM shown as Table 1 by the new SAM given in Table 6. This shows that the make matrix $T_{a l}$ is unaltered by these operations while the marketing matrix disappears along with the accounts for final comodities. The absorption matrix now shows activities as buying basic commodities as inputs, and value added by each activity must now be augmented by the cost
of imports and the indirect tax content of final commodities to maintain the balance of the SAM. Similarly, final demand is now expressed as a demand for basic commodities only. Table 6 is well known as the format which Stone developed for the representation and analysis of comodity balances.

Table 7 translates the details of Table 6 into the notation provided by equations (1), (2), (5), (6) and (9). In addition, the notation $\phi_{1}{ }^{*}$ and $\pi_{a}{ }^{\star}$ is introduced such that

$$
\begin{equation*}
\phi_{1}^{*}=\phi_{1}+\mathrm{L}_{12} \phi_{2} \tag{27}
\end{equation*}
$$

and $\quad \pi_{a}{ }^{*}=\pi_{a}+L_{2} a^{\prime} \pi_{2}$

And from this it is straightforward to derive the row and column balance equations which are presented in Table 8. The Stone model is now defined by the set of equations given in Table 8 as restricted by the assumption that the coefficient matrix $L_{12} L_{2 a}$ is fixed independent of all prices and quantities.

[^14]\[

$$
\begin{equation*}
\mathrm{q}_{2}=\overrightarrow{\mathrm{L}}_{2 \mathrm{a}} \mathrm{q}_{\mathrm{a}}+\phi_{2} \tag{29}
\end{equation*}
$$

\]

Table 7
An a Mernative version of Table 6

|  | Activities | Barrie <br> comma <br> -intis | All other <br> accounts | Totals |
| :--- | :---: | :---: | :---: | :---: |
| Activities | 0 | $\hat{q}_{a} s_{1 a}^{\prime} \hat{p}_{1}$ | 0 | $\hat{p}_{a} q_{a}$ |
| Basie commodities | $\hat{p}_{1} L_{12} L_{2 a} \hat{q}_{a}$ | 0 | $\hat{p}_{1}\left(\phi_{1}+L_{2} \phi_{2}\right)$ | $\hat{p}_{1} q_{1}$ |
| All other accomita | $\left(\pi_{a}^{\prime}+\pi_{2}^{\prime} h_{a}\right) \hat{q}_{a}$ | 0 | $*$ | $\cdots$ |
| Totals | $q_{a}^{\prime} \hat{p}_{a}$ | $q_{1}^{\prime} \hat{p}_{1}$ | $\cdots$ |  |

Note: $\phi_{1}^{*}=\phi_{1}+L_{12} \phi_{2}$ and $\pi_{a}^{*}=\pi_{a}+L_{2 a}{ }^{\prime} \pi_{2}$

Table 8
The balance equations implied by Table 7

| Account | Row equation | Column equation |
| :--- | :--- | :--- |
| Attrition | $p_{a}=S_{1 a}^{\prime} p_{1}$ | $p_{a}^{\prime}=p_{1}^{\prime} L_{12} L_{1 a}+\pi_{a}^{\prime}+\pi_{2}^{\prime \prime} L_{2 a}$ |
| Basic commodities | $q_{1}=L_{12} L_{2 a} z_{a}+\phi_{1}+L_{12} \phi_{2}$ | $q_{1}^{\prime}=q_{a}^{\prime} S_{1 a}^{\prime}$ |
| All other accounts | $p_{1}^{\prime}\left(\phi_{1}+L_{a} \phi_{a}\right)=\left(\pi_{a}^{\prime}+\pi_{2}^{\prime} L_{2 a}\right) q_{a}$ |  |

Note: $\phi_{1}^{*}=\phi_{1}+L_{12} \phi_{2}$ and $\pi_{a}^{*}=\pi_{a}+L_{2 a}^{\prime} \pi_{2}$

$$
\begin{equation*}
P_{2}{ }^{\prime}=P_{1}{ }^{\prime} \vec{L}_{12}+\pi_{2}{ }^{\prime} \tag{30}
\end{equation*}
$$


#### Abstract

Both of these conditions are, of course, satisfied under the conditions of the general linear model as can be seen from equations (20) and (23). It then follows that any solution of the Stone model must be consistent with the solution of the general linear model previously discussed. Accordingly, if the general linear model can be solved, then the Stone model can be solved since the solution of the latter is a reduced form of the solution of the former which can be obtained by substituting out the variables $q_{2}$ and $P_{2}$ from the general linear model according to the expressions (29) and (30).


```
It follows from this argument that the Stone model can always be solved in the same spirit that the general linear model can always be solved. But this does not imply that the condition (26) will necessarily be satisfied. In order for that to be the case, the notion of commodity technology must be elaborated.
```

Suppose that there is a unique technique for producing each basic comodity and that these techniques are described by $\tilde{L}_{21}$ and $\tilde{\pi}_{1}$ where $\tilde{L}_{21}$ is a matrix of fixed coefficients showing the intermediate inputs of final commodities which are needed to produce one unit of each basic commodity,

```
and \mp@subsup{\tilde{\pi}}{1}{}}\mathrm{ is similarly a vector of the net output prices
of the various commodities i.e. the value added per unit
for each commodity - producing technique. It then follows
that if }\mp@subsup{\overline{S}}{la}{}\mathrm{ is a matrix which shows the commodity composition
of unit output for each activity then
```

$$
\begin{equation*}
\bar{L}_{2 a}=\widetilde{L}_{2 a} \bar{S}_{1 a} \tag{31}
\end{equation*}
$$

and

$$
\begin{equation*}
\pi_{a}^{\prime}=\tilde{\pi}_{1}^{\prime} \bar{s}_{l a} \tag{32}
\end{equation*}
$$

i.e. that the intermediate input requirements of each activity and each commodity - producing technique are related as in equation (31); and the net-output prices of activities and techniques are similarly related, as in equation (32).

The Stone model can now be defined as a specialisation of the general linear model such that
(i)

$$
\vec{S}_{1 a}{ }^{-1} \text { exists; }
$$

(ii) $\quad \tilde{L}_{2 a}=\bar{L}_{2 a} \bar{S}_{1 a}-1$ is a non-negative matrix; and
(iii) $\quad \tilde{\pi}_{1}^{\prime}=\pi_{a}^{\prime} \bar{S}_{1_{a}}{ }^{-1}$ is strictly positive.

An immediate implication of (i) is that the number of activities and the number of basic commodities must be equal which, as previously suggested, is a severe restriction. And the result which must now be established is, that if the above
three conditions are satisfied, then the condition (26) will be satisfied.

To establish this result it can be noted that

$$
\begin{equation*}
\bar{S}_{1 a}-\bar{L}_{12} \bar{L}_{2 A}=\left(I-\bar{L}_{12} \bar{L}_{2 a} \bar{S}_{1 a}-1\right) \bar{S}_{i a} \tag{33}
\end{equation*}
$$

if assumption (i) is satisfied, so that the condition (26) will be satisfied if

$$
\begin{equation*}
\left(I-\bar{L}_{12} \bar{L}_{2} \overline{\mathrm{~S}}_{1 a}{ }^{-1}\right)^{-1} \text { exists } \tag{34}
\end{equation*}
$$

Now $\overline{\mathrm{L}}_{12}$ is a non-negative matrix and so is $\overline{\mathrm{L}}_{2 \mathrm{a}} \overline{\mathrm{S}}_{1 a}{ }^{-1}$ if condition (ii) is satisfied. Hence the condition (34) will be satisfied if

$$
\begin{equation*}
i^{\prime}\left(\bar{L}_{12} \bar{L}_{2 a} \bar{S}_{1 a^{-1}}\right)^{\Theta} \rightarrow 0 \text { as } \theta \rightarrow \infty \tag{35}
\end{equation*}
$$

But

$$
\begin{equation*}
i^{\prime} \bar{L}_{12} \bar{L}_{2 a} \bar{S}_{1 a}=\left(i-\pi_{2}\right)^{\prime} \bar{L}_{2 a} \bar{S}_{1 a}-1 \leq i^{\prime} \bar{L}_{2 a} \bar{S}_{1 a}-1 \tag{36}
\end{equation*}
$$

from (14) and an assumption that $\pi_{2}$ is non-negative. And

$$
\begin{equation*}
i^{\prime} \bar{L}_{2 a} \bar{S}_{1 a^{-1}}=\left(i-\pi_{a}\right)^{\prime} \bar{S}_{1 a}=\left(i-\widetilde{\pi}_{1}\right)^{\prime} \tag{37}
\end{equation*}
$$

from (16), (19) and (32). Hence

$$
\begin{equation*}
i^{\prime} \bar{L}_{12} \bar{L}_{2 a} \bar{S}_{1 a}^{-1} \leq\left(i-\tilde{T}_{1}^{\prime} \leq \lambda i^{\prime}\right. \tag{38}
\end{equation*}
$$

where

$$
\begin{equation*}
\lambda=1-\min \left(\tilde{\pi}_{1}\right) \tag{39}
\end{equation*}
$$

and $\min \left(\tilde{\pi}_{1}\right)$ is the smallest element of the vector $\tilde{\pi}_{1}$. Hence, from (38),

$$
\begin{equation*}
i^{\prime}\left(\bar{L}_{12} \bar{L}_{2 a} \bar{S}_{1 a}^{-1}\right)^{\theta} \leq \lambda^{\theta} i^{\prime} \tag{40}
\end{equation*}
$$

From condition (iii) it follows that $\lambda$ must be less than one. Hence, from (40), it must follow that the condition (35) is satisfied. Accordingly, the condition (26) is satisfied under the Stone assumptions (i), (ii) and (iii) above.

A natural question to ask at this point is: what should be done if the Stone conditions are not satisfied e.g. if the matrix $\mathrm{L}_{1}$ a as calibrated via (15), (17) and (31) contains negative elements. Evidently, there are three possible responses, of which the first is to do nothing on the grounds that the model is at best an approximation. The remaining possibilities are to change the data or to change the model.

```
Since the model is callibrated from a SAM for some base period it follows that a change in the data will effect the callibration and hence, potentially, might change the sign of particular coefficients such as the elements
```

```
of L2a. This is one possibility. Another is to change
the SAM more radically by changing the number of accounts
through aggregation or disaggregation. This is an option
which is often recommended since disaggregation potentially
reduces the amount of joint production and, therefore, reduces
the scope for problems to arise.
```

Changing the model is the second major option.
It has two variants, of which one is to retain linearity but replace Stone's commodity technology approach by the industry technology alternative. The other is to move to a non-linear model.

```
The general linear model which can be generated under the industry technology assumption will have a solution if all elements of \(v_{a}\) are positive in the base-period SAM and none of the remaining elements is negative. And in this case the solutions will provide a determination of all \(q^{\prime} s\) for given \(\phi^{\prime} s\), and all \(p^{\prime} s\) for given \(\pi^{\prime} s\). But is that an advantage, given that the industry technology assumption is less realistic than the commodity technology alternative, and both formulations break down when the existence of competitive imports must be admitted? The preferred way forward must be to generalise the linear model by allowing for both complementary and competitive imports while retaining the essential commodity technology assumption that each activity can produce more than one basic commodity.
```


### 4.1 Modeling the make matrix

The linear model represents a particularly severe restriction of the general system described by the equations in Table 5. To obtain more realistic models, it is necessary to consider more flexible formulations of the matrices $S_{l a}$, $\mathrm{L}_{12}$ and $\mathrm{L}_{2}$ a which allow them to be determined as functions of prices $P_{a}, P_{1}$ and $P_{2}$, and quantities $q_{a}, q_{1}$ and $\mathrm{q}_{2}, \mathrm{q} 3$. In particular, attention can be focussed on the determination of the make matrix $S_{1 a}$ and the desirability of making some allowance for competitive imports. The first of these concerns is addressed in this section; the second is taken up in section 4.2.

```
The modeling of the make matrix S1a requires
a determination of how much of its various products an industry
will produce, given its overall level of activity. If q
is the level of activity and }\mp@subsup{x}{1}{},\mp@subsup{x}{2}{}\ldots...\mp@subsup{x}{n}{}\mathrm{ are the output
levels for the various products, then there will be a technological
constraint of the form
```

$$
\begin{equation*}
q=q\left(x_{1}, \ldots x_{n}\right) \tag{41}
\end{equation*}
$$

which is illustrated in Figure $\mathrm{l}(\mathrm{a})$ for the case $\mathrm{N}=2$ by a set of iso-product curves which show the alternative combinations of $x_{1}$ and $x_{2}$ which correspond to a given level of

Figure /
Tranx Xormation by a multi-poonct firm


1(b): General case


1(c): Perfeet substitates
1(d): Peoflest complemmbt (lomit as $\tau \rightarrow \infty$ ) (lomitas $z \rightarrow 0$ )



```
q. To avoid unnecessary complications, the iso-product
curves are assumed =0 je concave to the origin and the further
the curve lies Erom the origin, the higher the level of
q which it represents.
```

If production costs are independent of $x$ for given $q$ then, in order to maximise profits, a firm must maximise revenue for each given $q$. Figure 1 (a) also shows some iso-revenue curves. These are drawn as straight lines with the implied assumption that product prices are independent of the level of activity, again to avoid complications. Hence profits are maximised for each level of $q$ by choosing that mix of outputs which corresponds to the tangency of the iso-product and iso-revenue curves. Hence the industry will operate along the expansion path illustrated in Figure l(a). The characteristics of this path will then determine the mix of products corresponding to any given level of $q$.

As a specific illustration fo this approach it can be assumed that

$$
\begin{equation*}
q^{(1+\tau) / \rho \tau}=\sum \beta_{i}\left(x_{i} / \alpha_{i}\right)(1+\tau) / \tau \tag{42}
\end{equation*}
$$

with all the parameters $\alpha_{i}, \beta_{i}, \rho$ and $\tau$ being non-negative and the parameters $\beta_{i}$ being subject to the restriction that $\sum \beta_{i}=1$. It can then be shown that the isoproduct curves corresponding to (24) are concave and that

$$
\begin{equation*}
q=1 \text { if } x_{i}=\alpha_{i} \text { for all } i \tag{43}
\end{equation*}
$$

A typical iso-product curve for the function (42) is illustrated in Figure $1(b)$ for the case $n=2$. Its slope is given by

$$
\begin{equation*}
\frac{d x_{1}}{d x_{2}}=-\left(\frac{\beta_{2}}{\beta_{1}}\right)\left(\frac{\alpha_{1}}{\alpha_{2}}\right)^{1+1 / \tau}\left(\frac{x_{2}}{x_{1}}\right)^{1 / \tau} \tag{44}
\end{equation*}
$$

which is zero when $x_{2}$ is zero, and infinite when $x_{1}$ is zero for any $T>0$. Hence, provided that neither $P_{1}$ nor $P_{2}$ is zero, a point of tangency along the isoquant will be an interior point.

The limiting case which is reached as $\tau \rightarrow \infty$ is illustrated in Figure $1(c)$. It is characterised by the fact that the slope of the isoproduct curve is independent of the product mix. This implies that the activity can change its product mix without having to loose progressively

```
more of one product for the sake of producing more of another.
In this sense the two products are perfect substitutes in
production.
```

    This limiting case suggests that the elasticity
    $\frac{d \log \left(x_{2} / x_{1}\right)}{d \log \left(d x_{1} / d x_{2}\right)}=\Sigma$
is a useful index of the flexibility of an industry in changing its product mix. It is known as the elasticity of transformation, and the expression for $q$ implicit in (42) is known as a constant elasticity of transformation function.

A point of tangency is evidently no longer possible in the limit reached as $\tau \rightarrow \infty$ and the industry will specialise in the production of either $x_{1}$ or $x_{2}$ i.e. the equilibrium is to be found at point $Y$ or point $Z$, depending on which yields the higher revenue. The equilibrium will therefore be at point $Y$ if

$$
\begin{equation*}
P_{1}\left(\alpha_{1} / \beta_{1}\right)>p_{2}\left(\alpha_{2} / \beta_{2}\right) \tag{46}
\end{equation*}
$$

and at $Z$ if the inequality is reversed.

The other limiting case which is reached as $\tau \rightarrow 0$
is illustrated in Figure $1(d)$. In this case both products, $x_{1}$ and $x_{2}$ will be produced in fixed proportions defined by point $X$ in the figure, since total revenue will always
be a maximum at $X$ provided only that both $P_{1}$ and $P_{2}$ are positive. Accordingly, the case of joint production can be characterised as a situation in which the elasticity of transformation is zero.

A final point to note concerning the function (42) is that it is homogeneous of degree $P$. Hence the case $P=1$ corresponds to constant returns in the sense that the scale of output for the activity is proportional to the scale on which products are produced.

Maximising total revenue for a given level of $q$ as specified in equation (42) can be shown to imply a determination of output for each product, $x_{i}$, which is

$$
x_{i}=\alpha_{i} q^{1 / p}\left[\frac{\left(\alpha_{i} p_{i} / \beta_{i}\right)^{1+\tau}}{\sum \beta_{j}\left(\alpha_{j} j_{j} / \beta_{j}\right)^{1+\tau}}\right]^{\tau /(1+\tau)}
$$

from which it follows that a typical element of the make matrix $S_{l a}$ is given by

$$
\alpha_{i} q^{(1 / \rho)-1}\left[\frac{\left(\alpha_{i} p_{i} / \beta_{i}\right)^{1+\tau}}{\sum \beta_{j}\left(\alpha_{j} p_{j} / \beta_{j}\right)^{1+\tau}}\right]^{\tau /(1+\tau)}
$$

Under constant returns to scale $(P=1)$ this expression is independent of $q$ so that the make matrix is dependent only on relative prices in this case. It will be independent of relative prices also when $\tau=0$ ie. in the case of joint
production. Hence the linear model previously discussed implicitly implies constant returns and a zero elasticity of transformation, $\rho=1$ and $\tau=0$.

```
Since the price }\mp@subsup{\textrm{Pa}}{a}{\prime}\mathrm{ of the output of an activity
```

is defined by the relationship

$$
\begin{equation*}
p_{a} q=\sum p_{i} x_{i} \tag{49}
\end{equation*}
$$

it follows from the result (29) that

$$
\begin{equation*}
p_{a}=q^{(1 / p)-1}\left\{\sum \beta_{j}\left(\alpha_{j} p_{j} / \beta_{j}\right)^{1+\tau}\right\}^{1 /(1+\tau)} \tag{50}
\end{equation*}
$$

which reduces to $\sum \alpha_{j} p_{j}$ when $p=1$ and $\tau=0 . \quad$ In general the result (32) implies that

$$
\begin{equation*}
x_{i}=\alpha_{i}\left(\frac{\alpha_{i} p_{i}}{\beta_{i} p_{a}}\right)^{\tau} q^{1-(1+\tau)(1-1 / p)} \tag{51}
\end{equation*}
$$

from which it can be seen that the proportions in which different products are produced will depend on their relative prices for as long as $\tau>0$. And as $\tau \rightarrow \infty$, the output mix moves towards complete specialisation in that product for which $\left(\alpha_{i} p_{i} / \beta_{i}\right)$ is a maximum. In this limit, the industry price, $P a$ is given by

$$
\begin{equation*}
\left.p_{a}=q(1 / p)-1 \quad \alpha_{k} P_{k} / \beta_{k}\right) \tag{52}
\end{equation*}
$$

```
if (\alpha}\mp@subsup{|}{i}{}\mp@subsup{P}{i}{}/\mp@subsup{\beta}{i}{})\mathrm{ is a maximum for product k. Hence }\mp@subsup{x}{i}{}\mathrm{ is
```

given by the limit as $r \rightarrow \infty$ of

$$
\begin{align*}
& \quad \alpha_{i} q^{l / p}\left(\frac{\alpha_{i} p_{i} / \beta_{i}}{\alpha_{k} p_{k} / \beta_{k}}\right)^{\tau}  \tag{53}\\
& \text { i.e. } \quad \begin{aligned}
x_{i} & =\alpha_{i} q^{1 / p} \quad \text { for } i=k \\
& =0 \quad \text { otherwise }
\end{aligned}
\end{align*}
$$

```
The point has been made in relation to the SAM shown as Table 1 that the individual final commodities which are implicitly recognised there can be grouped into five categories as suggested in Table 2. In relation to two of these, namely the non-traded goods and complementary imports, it may be reasonable to assume that intermediate usage by each activity is largely independent of prices and proportional to the level at which the activity operates with the coefficient of proportionality being fixed by technology. In these cases, the fixed coefficients assumed as a part of the linear model represent a reasonable approximation. However, in relation to competitive imports and the domestic goods they compete with, such an assumption is clearly not appropriate and the model must be developed if it is to be considered realistic.
```

Historically, the main line of development has been through activity analysis, whereby the market is assumed to favour competitive imports or the competing domestic good according to which is cheaper. Hence imported and domemstic goods are treated as being pure substitutes in this approach.

```
This reformulation in terms of activity analysis overcomes the immediate problem posed by the linear inputoutput model. However, the reformulation has its own inherent
```


#### Abstract

weakness and this was exposed by Samuelson [1951] through the non-substitution theorem. Specifically, the activity analysis formulation implies that countries should specialise their production of traded goods in the long run. By common consent in a period when planning remained in vogue, this implication was generally thought to represent a limitation of the approach.


To overcome this limitation Armington [1969] was the first to introduce the idea of composite commodities to allow for competition between domestic and imported goods in a more flexible way.

Table 9 sets out a SAM which represents a development of Table 1 by allowing for the existence of what Armington referred to as composite commodities. The essential idea here is to set at zero the entries in Table $l$ which refer to intermediate and final demand for competitive imports and the domestic goods which compete with them. Instead, these competing final goods are sold to the composite commodity accounts. The role of these accounts ex post is to record and, ex ante, to model the choices of the market among goods which compete, i.e. to determine the proportions in which competing goods will be demanded. In the extreme case when domestic and imported goods are perfect substitutes, these proportions may be determined on an all-or-nothing basis, i.e. the market will specialise on the cheaper source. This is the special case which corresponds to activity analysis.
Table 9
An extended version of Table 1 mintorncing composite commodity accomis

|  |  | Activitios | Commodities |  |  |  | Totals |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  |  | Basic | Final | Composite |  |  |
| Activities |  |  | 0 | $T_{a 1}$ | 0 | 0 | 0 | $y_{a}$ |
| $\cdots$ | Beoic | 0 | 0 | $T_{1 / 2}$ | 0 | $f$ | $y_{3}$ |
| - | Final | $T_{2 a}$ | $\bigcirc$ | 0 | $T_{23}$ | $f_{2}$ | $y_{2}$ |
| ${ }^{3}$ | Composite | Tan | 0 | 0 | 0 | $f_{3}$ | $y_{3}$ |
| All other accounts |  | $v_{a}^{\prime}$ | 0 | $v_{2}{ }^{\prime}$ | 0 | * | .. |
| Totals |  | $y_{a}^{\prime}$ | $y_{1}{ }^{\prime}$ | $y_{2}^{\prime}$ | y' | . |  |

```
More generally, when competing goods are less-than-perfect
substitutes, the market is likely to favour some mixture.
Hence combinations of competing goods, known as composite
commodities, are defined. And it is these combinations
which are purchased as intermediate inputs or as a part
of final demand.
```

A particular implication of this approach is that there are now two parts to the absorption matrix viz. T2a and $T_{3 a}$. The non-zero parts of $T_{2 a}$ result from intermediate purchases of non-traded goods and complementary imports, while the non-zero elements of $T$ 3a are the result of intermediate purchases of composite goods. To assume that matrices of fixed coefficients may underly both parts of the absorption matrix, $T_{2 a}$ and $T_{3 a}$, may now be a reasonable approximation. But this is because the innovation of matrix $T_{23}$ allows for explicit recognition of the sensitivity of demand to relative prices.

To formalise these ideas it can be suggested that a composite good, $q$, can be generated by combining inputs of other goods $x_{1}, \ldots, x_{m}$ as required by some functional relationship

$$
\begin{equation*}
q=q\left(x_{1} \ldots \ldots x_{m}\right) \tag{55}
\end{equation*}
$$

```
An iso-product curve in this case is generally assumed to be convex from the origin in recognition of the fact that
```



```
increasing quantities of one good are needed to compensate
for the loss of successive units of some ocher - a diminishing
marginal race of substitution. This is illustrated for
the case of m=2 in Figure 2(a) and reflected in the definition
of the elasticity
```

$$
\begin{equation*}
\frac{a \log \left(x_{1} / x_{2}\right)}{x i \operatorname{}\left|d x_{1} / d x_{2}\right|}=J \tag{56}
\end{equation*}
$$

implies a constant elasticity of substitution between all pairs of ingredients $x_{i}$ and $x_{j}$ for $i, j=1,2 \ldots m$.

> There are three special cases of this function which are interesting. When $\sigma$ is infinite the various ingredients $x_{1} \ldots x_{m}$ are perfect substitutes for each other and the rate of substitution (the slope of the iso-product curve) is independent of the input mix. This special case is illustrated in Figure 2(b) and corresponds to a version of (57) which is

$$
\begin{equation*}
\mathrm{q}^{1 / p}=\sum\left(s_{i}, x_{i}\right) x_{i} \tag{58}
\end{equation*}
$$

```
The opposite limit is reached as \sigma->人. This is the case
of zero substitution assumed in the linear model. It implies
that the ingredients of a composite commodity must be combined
in fixed proportions, so that imports and domestic goods
are in fact complementary. The expression (57) reduces
in this case to
```

$$
\begin{equation*}
q^{1 / P}=x_{k} / \alpha_{k} \tag{59}
\end{equation*}
$$

where $x_{k} / \alpha_{k}$ is the minimum of $\left(x_{1} / \alpha_{1}\right), \ldots,\left(x_{m} / \alpha_{m}\right)$. This limit is illustrated for the case of $m=2$ in Figure 2(c).

In between these two extremes is the case $\sigma=1$ which provides an important dividing line. In this special case, the relationship (57) takes on the special form

$$
\begin{equation*}
q^{1 / p}=\prod\left(x_{i} / \alpha_{i}\right)^{\sigma_{i}} \tag{60}
\end{equation*}
$$

which is familiar as a Cobb-Douglas function.

The sense in which the Cobb-Douglas case provides a useful dividing line can be explained as follows. When $5>1$, the isoproduct curves touch both axis as illustrated in Figure 3(a). This reflects the fact that for $q$ to be positive requires only that at least one of the ingredients should be positive. And when this condition holds, the ingredients are said to be strong substitutes.

$$
\begin{array}{r}
3(a): \text { Strong substitutes } \\
(\sigma>1)
\end{array}
$$

$$
x_{2}
$$

```
    In contrast with the above situation, when 0<\sigma< 1
all inputs must be positive in order that output of the composite should be positive. In this case, which is illustrated in Figure \(3(\mathrm{c})\), the ingredients are said to be weak substitutes.
```

In the intermediate, Cobb-Douglas case, the isoproduct curves are asymptotic to the axis as illustrated in Figure 3(b).

To develop the analysis it can be assumed that the supply of the ingredients is perfectly elastic at prices Pl... $P_{\text {m }}$. The market then behaves so as to minimise the total cost of supplying a given amount of the composite commodity. The mix of ingredients is therefore determined by the point on the expansion path in Figure 2(a) which corresponds to the required supply of the composite. This implies that in the case defined by the form (57) of the relationship (55) the requirement of ingredient $x_{i}$ will be given by

Hence $x_{i}$ is a homogeneous function of degree zero in the prices $P_{1} \ldots P_{m}$ and, therefore, so is each element of the matrix $L_{23}$.

```
If Pc is the price of some composite commodity
```

then

$$
\begin{equation*}
P_{c} q=\sum p_{i} x_{i} \tag{62}
\end{equation*}
$$

and the result (43) now implies that

$$
\begin{equation*}
P_{c}=q(1 / \rho)-1\left\{\sum \beta_{j}\left(\alpha_{j} p_{j} / \beta_{j}\right)^{1 \cdot \sigma}\right\}^{1 /(1-\sigma)} \tag{63}
\end{equation*}
$$

The result (43) can therefore be written in the more concise form

$$
\begin{equation*}
x_{i}=\alpha_{i}\left(\frac{\alpha_{i} p_{i}}{\beta_{i} p_{e}}\right)^{-\sigma} q^{1-(1-\sigma)(1-1 / p)} \tag{64}
\end{equation*}
$$

When ingredients are complementary, $\sigma=0$ and the result (64) yields

$$
\begin{equation*}
x_{i}=\alpha_{i} q^{l / p} \tag{65}
\end{equation*}
$$

When $\sigma=1$, the Cobb-Douglas case, the expression (63) for the price of the composite good takes on the limiting form

$$
\begin{equation*}
p_{c}=q(1 / \rho)-1 T T\left(\alpha_{j} p_{j} / \beta_{j}\right)^{\beta_{j}} \tag{66}
\end{equation*}
$$

and the result (64) can now be written as

$$
\begin{equation*}
x_{i}=\beta_{i} q^{1 / p} T\left(\alpha_{j} p_{j} / \beta_{j}\right)^{\beta_{j} / p} / p_{i} \tag{07}
\end{equation*}
$$

And, finally, as $\Gamma \rightarrow \infty$, the price of the composite good tends to the limiting form

$$
\begin{equation*}
P_{c}=q(1 / \rho)-1\left(\alpha_{k} P_{k} / \hat{\beta}_{k}\right) \tag{68}
\end{equation*}
$$

where $X_{k P k} / \beta_{k}$ is the minimum for all $i$ of $\left(\alpha_{i} P_{i} / \beta_{i}\right)$. It then follows that $x_{i}$ must be equal to the limit as $J \rightarrow \infty$ of

$$
\begin{equation*}
\alpha_{i}\left(\frac{x_{i} p_{k} / \beta_{k}}{x_{i} p_{i} / \beta_{i}}\right) 2^{i / p} \tag{69}
\end{equation*}
$$

Hence

$$
\begin{align*}
x_{i} & =X_{i} \text { ql/P } & & \text { for } i=k \\
& =0 & & \text { otherwise } \tag{70}
\end{align*}
$$

### 4.3 The general system revisited

The results provided in 4.1 and 4.2 above for modeling the make matrix and competitive imports are useful in their own right as specific formulations which might be adopted in particular cases. They also serve to suggest ways in which the very general system of equations previously presented in Table 5 can usefully be developed.

With Table 9 as the starting point and introducing a new notation:

$$
\begin{equation*}
\mathrm{T}_{23}=\hat{\mathrm{P}}_{2} \mathrm{~L}_{23} \hat{\mathrm{q}}_{3} \text { and } \mathrm{T}_{3 \mathrm{a}}=\hat{\mathrm{P}}_{3} \mathrm{~L}_{3 \mathrm{a}} \hat{\mathrm{q}}_{\mathrm{a}} \tag{71}
\end{equation*}
$$

and $\quad y_{3}=\hat{p_{3}} q_{3} \quad$ and $\quad f_{3}=\hat{p_{3}} \phi_{3}$
an alternative $S A M$ can be generated as in Table 10. The row and column balance equations of this new SAM define a general (non-linear) model of commodity balances which can be interpreted as an elaboration of the model defined in Table 5. The eight independent equations which define this more elaborate model are set out in Table ll, together with the redundant residual balance equation.

A linear model can now be obtained by assuming that each of $S_{1 a}, L_{2}, L_{2 a}, L_{23}$ and $L_{3 a}$ is a matrix of fixed coefficients. And, at the opposite extreme, a totally flexible model can be formulated in which each of these
Table 10
An alternative verscion of Table 9
Price

Table "
The balance equations implied by Table 10


```
matrices is treated as a function of both p and q where
p is a vector of all prices }\mp@subsup{P}{a}{\prime},\mp@subsup{P}{1}{},\mp@subsup{P}{2}{}\mathrm{ and }\mp@subsup{P}{3}{}\mathrm{ , and }
is a vector of all quantities qa, q1, q2 and q3.
```

```
In between these extremes are a number of interesting
cases which the analyst is likely to want to adopt in practice.
For example, the discussion of the make matrix in section
4.1 above suggests that this might be written as
```

$$
\begin{equation*}
S_{1 a}=S_{1 a}\left(P_{1}\right) \tag{73}
\end{equation*}
$$

with the understanding that each element of $S_{l a}$ is a homogeneous function of degree zero in the product prices $P_{1}$. And an implication of this approach would be that the output of an activity, $q_{a}$, is a linear homogeneous function of the quantities of basic comodities it produces.

```
Similarly, the matrix L23 might be written as
```

$$
\begin{equation*}
\mathrm{L}_{23}=\mathrm{L}_{23}\left(\mathrm{P}_{2}\right) \tag{74}
\end{equation*}
$$

with the implication that the supply of a composite commodity
is a linear homogeneous function of the quantities of constituent competitive goods, and a homogeneous function of degree zero of their prices.
Given (73) and (74) the model specification
might be completed in a particular case by assuming that

```
for the marketing and absorption matrices it is indeed reasonable
to postulate fixed coefficients, independent of all prices
and quantities.
```

This illustration of how a particular model might be specified has some, but not necessarily all of the characteristics of a special class of models which have a special independence property, namely that:

```
for any given \(\pi_{a}\) and \(\Pi_{2}\), all prices
\(P_{a}, P_{1}, P_{2}\) and \(P_{3}\) are uniquely deter-
mined independent of the scale of activity,
\(\mathrm{q}_{\mathrm{a}}\), and of commodity flows \(\mathrm{q}_{1}, \mathrm{q}_{2}\) and \(\mathrm{q}_{3}\).
```

There are in fact two conditions which are necessary if this independence property is to be satisfied, the first of which is indeed met in the hypothetical case previously discussed by way of illustration. This is the assumption of constant returns to scale throughout the commodity balance system. It requires that composite commodities $\mathrm{q}_{3}$ should be linear homogeneous functions of competitive commodities; and that both final comodities $\mathrm{q}_{2}$ and activity outputs $q_{a}$, should be linear homogeneous functions of basic comodities $q_{1}$. It also requires an absence of economies of scale in the determination of the make matrix. Under these conditions $S_{1 a}, L_{12}, L_{23}, L_{2 a}$ and $L_{3 a}$ will all be independent of $q$. Which does not imply that $\pi_{a}$ or $\pi_{2}$ must be independent of $q$. On the contrary, the independence condition is quite consistent with the notion that

$$
\begin{equation*}
\pi_{a}=\pi_{a}(p, q) \text { and } \pi_{2}=\pi_{2}(p, q) \tag{75}
\end{equation*}
$$

```
and, therefore, with non-constant returns to scale in the
generation of net output, or increasing net output prices
as a result of fixed factor inputs.
```

Given the necessary homogeneity of the commodity balance model, the five matrices $S_{1 a}, L_{12}, L_{23}$ and $L_{3 a}$ will all be independent of $q$. And in these circumstances Table 11 provides $2 a+n_{2}+n_{3}$ equations in prices $\mathrm{Pa}_{\mathrm{a}}, \mathrm{P}_{1}, \mathrm{P}_{2}$ and $\mathrm{P}_{3}$, together with $\pi_{a}$ and $\pi_{2}$. It then follows that the second necessary condition in order for prices to be determined uniquely for given $\pi_{a}$ and $\pi_{2}$ and independent of quantities is that the number of activities a and the number of basic commodities $n_{1}$ should be equal.

If the independence property maintains, then this is of some interest in its own right. There is also an interesting corollary, which is that the general equilibrium model defined in Table 11 can be solved recursively: prices can be determined first as a function of $\pi_{1}$ and then quantities can be determined as a function of prices and $\phi$ i.e. the final demands, $\phi_{1}, \phi_{2}$ and $\phi_{3}$.

It follows from this observation that when either of the necessary conditions breaks down, then the general equilibrium defined in Table 11 is no longer recursive.

```
It must therefore be created as a simultaneous set of
2(a+n_ n+ n2 + n3) equations in the 2(a+n_ n+ n2 + n_ )
variables }\mp@subsup{p}{i}{}\mathrm{ and }\mp@subsup{q}{i}{}\mathrm{ for i = a, l, 2 and 3, }\mp@subsup{\pi}{a}{}\mathrm{ and }\mp@subsup{\mathbb{N}}{2}{
and pl, ;}2\mathrm{ and p3. It might be thought, therefore, that
a unique solution for given }\pi\mathrm{ 's and ' 
possible, albeit that such solutions may not always have
the property that p's are independent of the q's.
```

```
    This speculation can best be explored by setting
aside for now the possibility of non-constant returns in
the determination of commodity balances, so that a lack
of recursivity in the determination of commodity balances
may be attributed to a difference between the number of
activities and the number of basic commodities.
```

    If there are more activities than basic commodities,
    then the price equations in Table 11 dictate that the various
elements of $\pi$ cannot be independent. And this is what
one would expect from the economics of the case: if two
firms are producing an identical product then their net
output prices cannot be independent if they are to both
stay in business. Similarly, if there are more basic commodities
than activities, then quantities are overdetermined for
given prices and the various elements of final demand, $\phi$,
cannot be independent, But this, again, is not particularly
surprising or difficult in terms of the economics: constraints
on the structure of Einal demand are to be expected from the theory of consumer behaviour, for example, and in general

$$
\begin{equation*}
\phi_{i}=\phi_{i}(p, q) \text { for } i=i, 2,3 \tag{76}
\end{equation*}
$$

It follows from these arguments that, when the number of basic commodities is not equal to the number of activities, then it is not generally possible to solve the commodity balance system defined in Table 11 for any values of $\pi$ and $\phi$. The elements of these vectors must be therefore be interdependent, and the form of this interdependence is characterised by equations (75) and (76). Accordingly, if the number of activities and the number of basic commodities are not equal, then the determination of prices and quantities must depend on their influence in determining the vectors $\pi$ and $\phi$ which cannot, therefore, be exogenous. Hence, any attempt to generalise the modeling of comodity balances which does not rely on the assumption that the matrix is square must lead directly to general equilibrium modeling which extends beyond the confines of commodity balances to embrace the determination of $\pi$ and $\phi$ and, therefore, inter alia, such considerations as factor costs, the exchange rate and consumer behaviour.

As a footnote to this, the main conclusion of this paper, it can be noted that Stone's model of commodity balances has the independence property previously noted.

```
And not only that, because Stone's model is in fact the
only possible model of this type which avoids the assumption
of an industry technology and, at the same time, posesses
the additional property that, for given final demands, %,
all quantities are determined independently of prices, p.
Moreover, it is striking that, in the process of developing
a general equilibrum model, Stone should have embodied a
model of commodity balances which is self-contained and
does not require that the rest of the system be modelled
except, of course, for its own sake.
```


## Pootnotes

1 See Hicks [1942] and Meade and Stone [1957]. The earliest work of Meade and Stone was published as an appendix to U.K. [1941].

2 A third innovation of less practical relevance was the incorporation of asset accounts within the framework.

3 Some scope for competitive imports can be recaptured by treating them as negative exports. The implication of such a formulation is that all imports are either pure complements or pure substitutes.

4 The existence of (I-S $)^{-1}$ requires formal conditions to be met which, for present purposes, can be taken for granted.

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# THE "INPUT-OUPUT TABLE" (IOT) AS A CENTRAL ELEMENT IN THE COMPILATION OF THE NATIONAL ACCOUNTS 

When a country's economy is to be represented by the National Accounts, a complex measuring instrument has to be set up. The evaluation of the GDP and its distribution uses all of the available statistical sources and presupposes that they are perfectly linked. In this context, the compilation of detailed accounts provided by the National Accounts is a select tool in this evaluation. This tool is all the more valuable since the statistical information has certain shortcomings.

Therefore, the construction of the IOT as part of the National Accounts for the benchmark year and current years ensures a much higher quality measurement of macroeconomic aggregates, starting with the GDP.

This paper will develop this contention and will describe the general compilation approach that could be used. It will then show how the method can provide a certain evaluation of the informal economy in developing countries.

The content of this paper is the result of an experiment successfully carried out in several countries with highly diverse economic features.

## 1 -PRESENTATION

a) When the National Accounts Have Nothing to Do with the IOT

When the SNA was revised for the third time in 1968, it was decided to use the principle of incorporating the IOT into a full layout of the National Accounts. The cost of this decision was a momentous overhaul of the system itself, as mentioned in the introduction to the Blue Book: "The attempt to integrate such a table into a system of National Accounts leads to a whole range of problems that did not arise under the old SNA." The fourth revision of the SNA, which is currently being adopted, confirms this direction. It also formalizes the way in which such a table should be presented when integrated into the National Accounts.

However, this integration is addressed solely from the conceptual point of view. It is a question of establishing the theoretical link between input-output tables and the rest of the system, in particular as regards the two following approaches:

- The overall balance of goods and services and its breakdown by products;
- The production account of the national economy and its breakdown by industries.

From this standpoint, the IOT could be considered to be a mere instrument giving a detailed presentation of the Nation's main aggregates, which are assumed to have been calculated elsewhere. This way of looking at the issue is confirmed by the content of Chapter IX of the Blue Book, entitled: "Adaptation of the full system to the developing countries." Part of this chapter reads: "Third and fourth orders of priority have been assigned to the parts of the full system of national accounts which are not urgently required or which are particularly difficult to compile. (...) Though the input-output tablesof the full system are of considerable value in economic planning and

[^15]programming, these tables are inluded here in view of the problems of compiling them" (Para. 9.65). Nothing in the texts currently available on the fourth revision suggests that this viewpoint has changed.

Furthermore, the method used by a number of countries to compile their National Accounts confirms this approach. The GDP is obtained by totalling the production accounts put together using a limited number of industries. The final demand is evaluated as a whole and the accounts in constant prices are obtained by applying a unique deflator to the entire economy. In such countries, when the decision is made to construct an IOT, the task is not given to the National Accounts. The work is carried out independently, the consistency with the National Accounts is rarely ensured (whether for the values or even the concepts themselves), and the finalization of the table is limited to just one year, given the magnitude of the work in hand. Nevertheless, the IOT compiled in this way often provides greater detail on industries and products.

Finally, although the principle of integrating the IOT into the National Accounts has been accepted for over 20 years, it has to be said that it is slow in being applied. An explanation for this can undoubtedly be found in the above presentation: putting together an IOT is considered to be a luxury that is not required for the work of the National Accounts and can therefore be dispensed with, especially when resources are low. On the other hand, when the decision is made to put an IOT together, this is done so selectively on the perimeter of the National Accounts and in association with a specific need that funds it.

## b) The National Accounts Need the IOT

The theory defended in this paper is as follows:
It is not possible to satisfactorily assemble economic aggregates, especially the GDP, without processing of all of the available information in its entirety, which only the IOTs compiled each year can provide.

The IOT is unquestionably a select economic planning and programming instrument. However, my contention takes this fact further: the IOT is also an instrument of the utmost importance to the competent compilation of the National Accounts. I would even add that its compilation is all the more necessary when the statistical information available in the country is of poor quality!

It is therefore not necessary to expand on the advantages of the Leontiev matrix in analyzing the structure of a country's production system or in forecasting developments by inverting the technological coefficients matrix. In more general terms, the IOT forms part of the tools required for economic forecasting.

However, the IOT brings a much greater number of relationships into play. These relationships can be used for both forecasting and as a way of making all of the country's production information consistent.

The IOT presents a summary of three possible ways of calculating the GDP:

- The distribution of income approach,
- The final demand approach,
- The industry production accounts approach.

Information exists for each of these approaches, but it is incomplete. In the absence of an IOT, each approach needs to be worked through separately in order to measure the GDP. Therefore,
work has to be completed before being able to see the differences that necessarily separate the different values obtained ${ }^{2}$.

When the GDP is calculated in this way in the least developed countries, only one of the three approaches is actually used. The effect is that even less satisfactory results are obtained, for two reasons:

- Out of the already-sparse sources, only those relating to the selected approach can be used,
- The linear approach applied makes any test of consistency between these sources impossible.

Introducing the IOT into the accounts compilation approach proves to be the only way to overcome these two problems:

- By taking all of the available sources into account,
- By continually making the measured intermediate amounts consistent.

Optimal use can therefore be made of the contributions obtained from each of the abovementioned approaches.

Filling the IOT with elements from each of these approaches does more than just make them compatible with each other. It also allows a more effective exploration of the areas that statistics necessarily leaves in the dark. An instrument is finally available to provide a general summary of all of the flows associated with the GDP.

To sum up, it is worth mentioning some of the relationships able to be introduced by the use of the IOT in order to ensure such consistency:

- Market balances by product,
- Industrial chains,
- The reconstitution of costs associated with the production hypotheses eventually selected to satisfy the market balance,
- The breakdown of indirect taxes by industry or by product,
- The working out of product-by-product transport and trade margins,
- A cross-section analysis by industry and by product of GFCF and inventories.


## c) Assessment of the Advantages

It is always possible to draw up the National Accounts more inexpensively. A number of countries make do with a summary evaluation of their GDP, especially its use is limited to the requirements of international bodies. However, it is well known that such evaluations do not take account of the actual situation of the economies in question. In particular, there is a lack of knowledge concerning the informal economy and, more generally, concerning everything that escapes statistical collection (see Chapter 3 below).

The use of the IOT, with all the possibilities that it offers, as an instrument for drawing up the National Accounts therefore proves to be the best way of overcoming such problems. To be more specific, a list can be given of the advantages arising from such a compilation:

[^16]It allows an enormous amount of detail to be drawn from the information available. It is not essential to have an highly detailed IOT (some thirty industries can suffice for an underdeveloped economy). On the other hand, the industry-by-industry and product-by-product analytical work can be much more detailed (several hundred items).

- It swiftly reveals any inconsistencies between statistical sources and solves them. Either directly or through the relationships resulting from the IOT, differences often appear between the available sources without any apparent way of knowing which one should be preferred. The IOT makes it possible to compare them, make them compatible and eventually choose the solution considered to be the most satisfactory. Therefore, the best can be drawn from all the available information, including information external to the statistical field itself (especially everything concerning technical data supplied by the each activity's professionals).
- It allows statistical "black holes" to be evaluated. Even in the developed countries, and more so in the others, statistics cannot provide information on all of the aspects of economic life: failings in the statistical instrument, fields as yet unexplored, and areas that inevitably escape its scope (especially developments on the perimeters of legality such as moonlighting, tax evasion, contraband and drugs). The IOT helps to implement indirect methods and accounting or economic relationships that can be used to push back the grey areas. An example of this is given in Chapter 3 on the informal economy.
- It links the data on industries, goods and services with the data from institutional sectors. National accountants find this problem to be one of the most complicated to solve, at least when they draw up complete accounts. This concerns more particularly the following aggregates:

Output
Value added
Compensation of employees
Taxes on production and imports and subsidies
Gross fixed capital formation
Inventories and their changes.

- It allows the compilation of real accounts at constant prices (and not just accounts at constant purchasing power). The application of a unique deflator to the major aggregates merely allows accounts at constant purchasing power to be put together. The development of accounts at constant prices presupposes that the prices for each product are different for both their output and their various inputs. Only an annually-compiled IOT enables this dual weighted deflation to be made. IOTs can therefore be put together at current prices and at reference year prices.
- An annual compilation of the IOT allows consistency in time when processing the data and arbitrating. This consistency may rely in particular on the stability of technological coefficients over a given period of time, especially if a comparison is made of the IOTs for two successive years valued at the prices of one of the years in question.


## 2-A DECENTRALIZED COMPILATION PROCEDURE ${ }^{3}$

Putting together an IOT is a long-winded job. It is so long that it could be considered to be incompatible with the compilation of the National Accounts, whose publication cannot be too delayed and whose implementation necessitates a number of other tasks. In the name of experience, I can confirm the accountability of the two realizations. Naturally, the IOTs obtained may not provide all of the details that certain users would like (but in the case of Peru, for example, selective

[^17]support from the planning ministry allowed the two requirements to be combined for the IOT relating to the benchmark year). In addition, suitable compilation procedures need to be introduced. Those presented here were gradually perfected during projects with which I cooperated in various countries ${ }^{4}$.

Due to the magnitude of the work to be carried out, and in order to involve more people (over 25 in the case of Peru), such procedures count on the decentralization of tasks and responsibilities, the maximum circulation of information and a highly formalized management of the partial results obtained. Whenever these procedures have been applied under good conditions, the final and centralized phase of the summary has progressed swiftly and without any particular problems.

The presentation made here is limited to the case of the benchmark year. It can easily be transposed to the case of current years. The working period for the latter is a lot shorter due to the availability of all of the options chosen when the first year was compiled.

## Presentation of the Compilation Approach

Five main steps can be distinguished in the progress of the work to be carried out. Each step has to be finalized before moving on to the next (with the exception of the move from the second step to the third, which is to be carried out independently for each of the sources analyzed). The enclosed diagram shows the relevant characteristics.

[^18]

## Stage 1

This stage defines the conceptual and methodological contexts for the work to be carried out. It is normally only applicable when an IOT is first put together.

It is assumed that the countries respect the international recommendations for their concepts and definitions, which are now to be found in the fourth revision of the SNA (already implemented in Greece) and its associated classifications (ISIC and CPC). Later on, this document will use the concepts and terminology of the fourth revision of the SNA, according to its provisional version. However, local specifications need to be introduced. This can go as far as making certain changes to take account of specific situations in the country in question. It should be borne in mind that the approach is based on highly analytical work. This makes it necessary to propose a fine breakdown adapted to the classifications to be implemented. In this sense, local reality takes precedence over international demands.

The following are examples of what the methodological references cover:

- The inventory of available sources and their input conditions;
- The list of chains to be considered, with an inventory of their technical features;
- An expression of the classifications according to local reality, in particular as regards institutional units, market and non-market industries, taxes, etc.
- The valuation methods to be used.


## Stage 2

This stage covers the collection of all the available data. Timid behaviour is not acceptable when researching these data. The National Accounts owe it to themselves to be detective-like in finding all of the possible indices and examining them closely with an uncompromisingly critical eye. A few pointers can be given for the implementation of this method:

- One source is not enough to evaluate a category when several can be obtained;
- All information found is worth taking into consideration;
- Methodical doubt is the rule with regard to all of the available data (even the most credible);
- Information is available from more than just the Statistical Office; the various economic players should also be approached;
- The information is not purely economic; it is also legal, administrative, demographic, social, technical, etc.


## Stage 3

The sources are available in a wide variety of forms. Each source uses specific concepts and classifications usually linked to the characteristics of the field concerned. The purpose of the third stage is to transpose this information using the concepts and definitions of the National Accounts: the classifications on the one hand and the valuation method on the other. The basic data can be values, physical quantities, prices or even indices and other ratios. The aim is to set up a statistical data base that can be used using the criteria selected by the National Accounts without any further manipulation required.

The diagram shows all of the tables into which this information can be organized. This assumes that a considerable amount of source interpretation work has already been done. However, this work remains confined to each separate source. This stage is limited to noticing any divergences between the different sources for a given case.

## Stage 4

This stage deals with the analytical summary of all of the collected data. Two instruments play a fundamental role in this summary:

- The supplies and uses balance of goods and services (called the "commodity flows approach");
- The production and generation of income accounts by industry (within the framework of an analysis of their production function).

Both of these instruments are developed in great detail (100 to 200 for the industries and 200 to 600 for the products).

Whenever possible, suplies and uses balances are first calculated in physical quantities. Some of them form the subject of joint work from the point of view of production chains. Industry accounts are put together in connection with the production factors introduced (raw materials, work and fixed capital). Particular attention should therefore be paid to employment data. Work instruments are planned in such a way as to allow the gradual incorporation of hypotheses on the hidden economy (see the different columns proposed for the production and generation of income accounts by industry, the use of which is explained in Chapter 3).

Analytical work uses product-by-product and industry-by-industry information on the different operations in question. Pre-summary tables therefore have to be put together in order to ensure the consistency of local arbitration. This concerns in particular:

- The data available on interindustrial trade (use matrix),
- The production matrix (make matrix),
- The GFCF by product and by industry (and/or by institutional sector),
- A table of taxes on production and imports and subsidies,
- The change in inventories by product and by industry (and/or by institutional sector),
- The measurement of trade output,
- Employment by industry.


## Stage 5

This stage concerns the final synthesis. Once the commodity flows approach has been pursued and the industry accounts put together, all the resulting data are gathered together into the IOT and the other summary tables shown in the diagram.

The work therefore concentrates on four assignments:

- A critical analysis of the amounts obtained including GDP and the elements of final demand on the one hand, and the primary distribution and gross operating surplus by industry on the other;
- Arbitration as regards the table of intermediate consumption so that the supply data (put together within the framework of the balances) corresponds to the demand (from the industry production accounts);
- The transfer to the intermediate tables of all the corrections made during this fifth stage.
- The transposal by institutional sectors of the data that figures simultaneously in their accounts.


## 3-AN EXAMPLE: THE INFORMAL ECONOMY

The development of the informal economy in developing countries is a real challenge to the National Accounts insomuch as this activity usually escapes classic statistical collection. How should this phenomenon be evaluated and how can it be developed over a period of time? A closer examination shows that the challenge is even greater. It concerns all unrecorded statistics, of which the informal economy is only one aspect. Yet the National Accounts are supposed to measure all economic life (the documents on the fourth revision of the SNA stress this even more emphatically).

When the IOT is used according to the above-mentioned method, it contributes decisively to winning this challenge. It allows the exploration of grey areas concerning, in particular, all of the activities that develop on the perimeters of the formal economy. As a result, techniques adapted to the nature of each industry have been gradually set up to measure what statistics do not provide ${ }^{5}$.

However, the demand goes even further. It is worthwhile isolating the data that more specifically concerns what is called the informal economy from the rectifications made. This is because the above-mentioned techniques cannot make the necessary distinction. New measurement methods must consequently be planned, including the implementation of specific surveys. The IOT is also predominant in this area. The presentation of these methods is therefore a good example of the irreplaceable role that the IOT plays in the construction of the National Accounts ${ }^{6}$.

## a) Defining the Concepts

The introduction to this third chapter mentions the use of two intersecting notions: items not recorded by statistics and the informal economy. Some authors even tend to confuse the two. Yet it is important to make the right distinction between them in order to have a better command of them, as they come under different registers: one is statistical and the other is economic.

There is the entire area of statistical non-being represented by the fact that statustics do not record certain economic and social phenomena for various reasons that have to be differentiated. This is referred to as statistical non-recording. On the other hand, there is a considerable proportion of economic activity that develops outside of the controls and regulations decreed by the government. These activities are more or less punishable and/or use alternative methods. They are called informal activities. The first approach (statistical non-being) concerns the statistician's point of view. The second approach (an informal production system) is a matter for economists.

Experience has shown that statistical non-recording concerns all economic activities and affects all institutional sectors. Nevertheless, it is also true that the field of informal activities is more particularly concerned with this statistical shortcoming. This is why there is not enough information to measure its magnitude. A wide variety of methods has been designed to evaluate these activities. It has to be said that this statistical problem is not the only explanation for the shortcomings in the measurement of this economic phenomenon. The way in which the causes are interpreted also differs to such an extent that the very content of the "informal" phenomenon is badly defined and disagreement persists as to the definition of its outline.

For operational reasons, we propose the following definition of an "informal sector": all establishments (still called production units) situated on the perimeter of the government

[^19]regulations covering them, whatever their size or business may be. Such establishments necessarily belong to the institutional sector of households. The absence of tax registration (or the application of a flat tax rate) could therefore be the best objective criterion for "marking" the units deemed to be informal.

In the context of such definitions, most informal units are absent from the classic economic surveys. However, the phenomenon is not systematic and better coverage could be obtained during an economic census, for example. Nevertheless, the fact remains that the coverage rate is still an unknown.

For its part, statistical non-recording concerns still other phenomena:

- Certain special general government accounts;
- A share of the international aid received;
- Formal units (especially companies) absent from statistics for various reasons;
- The production of formal units not declared to statisticians (for tax evasion purposes or any other reason);
- Own-account household production;
- All illegal activities.


## b) For Direct Information on Informality

Statistical non-recording produces a negative notion, which the National Accounts has to address in its entirety. It is impossible to find specific information on the informal economy by means of non-recording. Consequently, a positive approach to the phenomenon is required. This approach is necessarily statistical and, as informality is only sparsely covered by classic economic surveys, new tools have to be conceived.

The first of the solutiors worth mentioning is the linking of the "enterprise census/informal sector survey". It is the most direct procedure, because it focuses on the production units in their real state right from the start of the study. The census can be carried out by random sampling, but it assumes that the surveyed areas have been systematically combed to ensure that all forms of activity are detected. Nevertheless, an actual house-to-house survey needs to be made in order to find the activities practised in homes. This still excludes non-sedentary activities.

This is why another course of action is currently being explored: carrying out mixed surveys on the basis of household employment surveys. The employment surveys provide the best filter for a specific survey on the informal sector. They supply the information required to identify all of the heads (unincorporated businessmen) of informal units, whether they are sedentary or not.

## c) The IOT Evaluation Method and Role

This work forms part of the approach presented in Chapter 2. The approach can lead to a relatively exhaustive exploration of the areas in which there is a lack of direct information. Such an exploration is even more successful when a rigorous typology of statistical non-recording is perfected for the country in question. Special investigations need to be made of some of these grey areas: missing government data, international aid, missing formal units and illegal activities.

For the rest, an overall evaluation of the unrecorded items can be obtained at the level of each industry by introducing relationships supplied by the IOT. In order to do this, each chain has to be put into perspective by taking account of the available strong points:

- National or imported raw materials,
- Production factors (including employment),
- The level of demand (intermediate, final consumption, capital formation and exports).

These evaluations also have to be recorded in the reference totals. Information on the different economic populations is used for this:

- The productive institutional units,
- The establishments,
- The working share of the labour force by industry (specifying, where possible, the number of jobs and the time worked).

This employment information is of the utmost importance. It is vital to put it into the form of a matrix that cross-references economic activity and worker status (employees, employers, ownaccount workers and home helps). Information from the latest population census and employment surveys are used for this. Such a structure can also receive information from the mixed survey on the informal economy when this has been carried out. It should be noted that this type of matrix allows a job to be allocated to the total known working proportion of the labour force.

At the end of these different tasks, the "production and generation of income accounts by industry" are put together. This is the fourth stage in the above outline. These accounts are compiled for each of the industries in question. They consist of:

The rows: the transactions of the production, generation of income and entrepreneurial income accounts, and the result obtained from the previous matrix concerning the population employed.

The columns: a breakdown of these data by family of establishments suing the following classification:
(1) Corporations
(2) Formal unincorporated enterprises
(3) Informal unincorporated enterprises
(4) Under-recording associated with cases (1) and (2)
(5) Own-account household production
(6) Establishments practising illegal activities.

When filling in this table:

- Columns (1) and (2) are completed using classic statistical sources,
- Column (3) is filled in using data from the above-mentioned specific survey,
- Columns (5) and (6) only concern a limited number of activities. It is nevertheless particularly difficult to estimate their content,
- Column (4) is obtained as a difference, taking account of the overall evaluation from the IOT. This under-recording is more often than not the result of tax evasion.

The use of an iterative approach gradually assigns the production functions belonging to each of these columns in such a way that the proposed total is compatible with the rest of the system. This method obviously still leaves some grey areas that only additional hypotheses can clarify. However, their weight is already much smaller. The method thus allows strong hypotheses to be proposed both on the informal economy and on tax evasion in the formal economy.

## 4-A FEW REMARKS BY WAY OF A CONCLUSION

1/ The compilation of IOTs unquestionably represents a great deal more work for the National Accounts. Nevertheless, the quality of the Accounts is at stake. If high quality is to be obtained, a price has to be paid for it. Bypassing the IOTs would make it difficult to significantly improve this quality. The political authorities must therefore be convinced of this.

2/ However, the extra cost that this represents should not be exaggerated, in comparison to an episodic compilation by a team working independently of national acounts. In fact, the same statistical work has to be carried out. Yet, instead of having to put together a new team each time, this team becomes permanent. The technological maintenance and continuity of the methods used are therefore ensured.

3/ The integration of the IOTs into the National Accounts provides both a sound IOT for the benchmark year (for the structural analysis) and successive IOTs for a given period of time in both current prices and constant prices. This also allows the time analysis to be made.

In the countries with which I worked, the IOTs in benchmark year prices were obtained by chain-linking IOTs put together at the prices of the previous year.

4/ The IOTs obtained in this way are generally less detailed than those put together by an independent team. This is because there is only a short space of time in which to update the National Accounts. However, greater detail can be provided for the benchmark year (as was done in Peru and Brazil).

Such IOTs offer the enormous advantage of being linked up with all of the other transactions analyzed in the National Accounts, such as:

Tax and subsidies,
Income flows,
Saving by sectors and the position in relation to the Rest of the World,
Balance sheet elements (fixed capital, inventories and financial instruments).

5/ There is a growing demand for more information on the household accounts and for details of its content (for example, within the framework of social accounting matrices). An independent development of these instruments can only introduce the direct information on them. However, the preliminary compilation of an IOT ensures that they are of better quality, because it allows such sources to be compared with information from the producers, foreign trade and the accounting data of institutional sectors. Moreover, it allows a synthesis to be made of the household accounts by comparing them with the accounts of other sectors. The social accounting matrices can therefore be given the macroeconomic grounding that they might otherwise lack.

## 6/ Comments on the Methods:

- The SNA proposes developing the IOT by using industries (establishment groupings), which simultaneously implies the construction of a make matrix. The European Community has up until now proposed the compilation of "pure" branches. Both methods are feasible. It should be noted, however, that the first method ensures a much better proximity to the statistical sources. In addition, the make matrix of underdeveloped countries is mainly diagonal.

Production at basic prices is the basis for arbitration on the supplies and uses balance, whereas the uses are provided at their purchasers' prices (due to the nature of the information provided by statistical sources). In order to make the transition from one to the other, associated taxes and margins must be evaluated. This basic material can then be used to construct matrices according to different types of valuation. The fourth revision of the SNA proposes that the IOT should normally be presented in purchasers' prices.

It could be very interesting to put together rectangular matrices (by linking several products to one industry). The information on the markets is more detailed than that relating to the technical coefficients for the industries. Should the matrix need to be inversed, it can always be returned to a square form. It is worth mentioning that computer technology allows iterative procedures to be implemented. These procedures are compatible with rectangular matrices and present a greater flexibility of use than the use of the inverse matrix.

# Evidence on IO Technology Assumptions from the Longitudinal Research Database 

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#### Abstract

${ }^{1}$ Board of Governors of the Federal Reserve System and research associate at the Center for Economic Studies (CES), U.S. Bureau of the Census. This paper presents the author's own views, not those of the Federal Reserve System or the Census Bureau. I owe thanks to many individuals for help on data issues, particularly Mike Mohr, Mark Planting, and several CES staff members. Joe Beaulieu gave helpful advice on nonparametric econometric techniques. The useful research assistance of Mark Kodini is gratefully acknowledged.


#### Abstract

This paper investigates whether a popular IO technology assumption, the commodity technology model, is appropriate for specific United States manufacturing industries, using data on product composition and use of intermediates by individual plants from the Census Longitudinal Research Database. Extant empirical research has suggested the rejection of this model, owing to the implication of aggregate data that negative inputs are required to make particular goods. The plant-level data explored here suggest that much of the rejection of the commodity technology model from aggregative data was spurious; problematic entries in industry-level IO tables generally have a very low Census content. However, there is a sound statistical basis for rejecting the commodity technology model in about one-third of the industries for which Census data on specified materials use is available: for each of these industries, a novel econometric test demonstrates heterogeneity of materials use among plants that only produce the primary products of the industry.


## 1 Introduction

In the input-output literature, a "technology assumption" is a means for disentangling the requirements for material inputs to meet a given final demand vector from observed data on the make and use of commodities by industries. The presence of secondary production can render understanding the relation between material inputs and the production of specific commodities more difficult. In a given industry, many establishments are likely to produce more than one type of commodity (Streitwieser (1990)), including commodities classified as primary to other industries. In the benchmark input-output accounts for the United States of BEA (1991), the use table gives only information on the composition of inputs for the industry as a whole, and one cannot infer from this data the composition of inputs to the production of the specific commodities made in the industry. A technology assumption is a means for disentangling the input structure for both primary and secondary products from the convolution of data in the use table.

The BEA (1991) presents a direct requirements matrix for the United States that embodies the industry technology assumption, as if the plants in an industry use a fixed "recipe" to make the bundle of commodities they produce; the material input requirements for a given commodity are assumed to depend only on the industry affiliation of the plants making that commodity, not on the nature of the commodity per se. In a series of papers, ten Raa and coauthors (1984, 1988, 1989) have argued that the industry technology assumption is fundamentally unsound and explored the viability of the commodity technology assumption, which proceeds as if the "recipe" for production of a commodity depends only on the nature of the commodity, not on the industry affiliation of the plant in which it is made.

Previous empirical research on IO technology assumptions generally has been limited to data pertaining to totals for all establishments within an industry. One cannot discern any variation in the product or input mix from such data, so competing technology assumptions were evaluated on grounds other than the correlations between product and input composition. For example, ten Raa, Chakraborty and Small (1984) proceed as if the presence of negatives in the Leontief inverse is sufficient for rejecting a technology assumption; they try to eliminate the negatives from the commodity technology Leontief inverse by defining a mixed technology model that also allows for
the presence of byproducts. However, not all of the negatives can be eliminated this way, so ten Raa (1988) and ten Raa and van der Ploeg (1989) consider a statistical approach that allows for the possibility of measurement error in the published make and use tables. In that work, it was assumed that the published tables were unbiased but imprecise estimators of the true make and use of commodities by industries. Using subjective estimates of the imprecision of specific coefficients, ten Raa (1988) and ten Raa and van der Ploeg (1989) found that the kind of reallocations of entries in make and use tables needed to eliminate negatives were implausible. Implicitly, plant-level technologies were treated as identical.

Here, I take a more direct statistical approach to examining the problem of negatives, using the variation across plants in reported product and input mixes to test the commodity technology assumption. Measurement error is modelled as the result of nonreporting of specified materials use by particular plants. Where reports on specified materials are available, the commodity technology model is estimated from the distribution of material input intensities among plants that are 'pure' in the sense that they make only the characteristic commodities of the industry. The commodity technology model is tested by seeing whether the material use patterns of pure plants are relatively homogeneous.

To preview the empirical results, I find that rejections of the commodity technology model from aggregate data generally are for the wrong reasons; the problematic entries in industry-level IO tables generally have a very low Census content and do not provide a sound statistical basis for the rejection of the commodity technology model. Second, I find that, when available, sometimes the micro-data do provide a sound reason for rejecting the commodity technology model; there is substantial heterogeneity of materials use among plants that only produce the primary products of an industry.

The next section of the paper reviews how industry-level aggregate data can generate the problem of negatives. Using plant-level data, the third section examines possible explanations for the problem of negatives. One of the major findings is that alot of heterogeneity underlies the aggregates in published input-output use tables, and the concluding remarks point to further work that would be useful for understanding and coping with the implications of this heterogeneity.

## 2 The Problem of Negatives

In the 'use' table $U$ of the U.S. IO accounts, entry $u_{i j}$ is the amount of commodity $i$ used as an intermediate input in industry $j$. In the 'make' table $V$, entry $v_{j k}$ is the amount of commodity $k$ produced by industry $j$. When the industry is the unit of observation, the commodity technology assumption is specified as the constraint that the use of a particular intermediate $i$ in the production of a given commodity $k$ is a fixed proportion $a_{i k}^{c}$ of the make of that commodity $k$, no matter the extent of other production in the industry:

$$
\begin{equation*}
u_{i j k}^{c}=a_{i k}^{c} v_{j k} \tag{1}
\end{equation*}
$$

This aggregative commodity technology model implies $U=A^{c} V^{\prime}$, or $A^{c}=$ $U V^{\prime^{-1}}$. The latter formula indicates that to infer direct requirements coefficients $a_{\dot{\boldsymbol{i}}}^{c}$ for a given commodity $k$ from industry-level use and make tables, one computes a weighted average of the use of the intermediate in question $i$ by all industries $j$, with weights $w_{k j}=v^{j k}$ from the inverse of the transposed make table that depend on the extent to which the commodity $k$ is made in each industry. Generally, many of the weights will be negative, reflecting the need to purge the total input of the intermediate in a given industry of the requirements for that input in producing the secondary commodities of that industry. IO researchers have found that in practice, some of the implied direct requirements coefficients are negative; for some intermediates, more use of an intermediate is purged than actually consumed.

For example, calculations from the benchmark U.S. input-output accounts for 1982 show that 363 commodity technology direct requirements coefficients for manufactured goods are negative and large in absolute value (line 1 , column 3 of table 1). Only about 5000 of the elements of this matrix are large in absolute value (to be exact, there are 5131 large elements, 4668 positive and 363 negative). Thus, more than 3 out of 50 , or 6 percent, of the large elements of the direct requirements matrix are negative.

## 3 Possible Explanations of Negatives

I consider two explanations for the negatives that appear to signal the failure of the commodity technology model: measurement error and heterogeneity among pure plants. The measurement error hypothesis is the possibility that the model (1) is literally true at the plant level, but the entries in the aggregative make and use tables are imprecise and possibly biased. Some researchers have argued that the problem of negatives often is derived from heterogeneity among pure plants in materials use intensities. For example, there can be significant variation in materials use intensities among the products that are primary, and aggregation of plants that make distinct primary products with very different materials use patterns can lead to the apparent anomaly of negative requirements. In this section of the paper, I consider each of these possible explanations for the failure of the commodity technology model on aggregate data.

### 3.1 Measurement Error and the Census Content of Use Tables

ten Raa (1988) and ten Raa and van der Ploeg (1989) emphasized measurement error in their statistical approach to re-estimating the published aggregate input-output tables for the U.K.. They assumed that the observed industry-level data $u_{i j}^{0}$. and $v_{j k}^{0}$. include measurement errors $\delta_{i j}$. and $\epsilon_{j k .}$, so that the relation between true values and observed values is:
(2) $u_{i j . .}=u_{i j . .}^{0}+\delta_{i j .}$.
(3) $v_{j k .}=v_{j k .}^{0}+\epsilon_{j k}$.

In principle, there also can be more disaggregative use and make tables with entries $u_{i j, m}^{0}$ and $v_{j k m}^{0}$ that record corresponding statistics for each plant $m$ within an industry. I offer an interpretation of equation (2) that makes the relation of the industry-level and plant-level statistics explicit.

Specifically, I assume that the plant-level statistics on the use of materials also might be measured with error:

$$
\begin{equation*}
u_{i j, m}=u_{i j, m}^{0}+\delta_{i j, m} \tag{4}
\end{equation*}
$$

but regard the degree of measurement error in the make statistics as negligible for the purposes of this study (i.e., $\epsilon_{j k m}=0$ ). This emphasis on uncertainty about use table entries is based on the nature of the underlying source data from the U.S. Census of Manufactures ${ }^{1}$. Relatively complete data on the primary/secondary product split is available, but almost all (98 percent) IO use table entries for manufacturing industries have a low Census content in the sense that they are not based on reports of specified materials use (last column of line 2 , table 1 ). In order to keep reporting burdens down, the Census questions on specified materials use are narrow in the sense that they cover few materials.

It is not clear whether this reporting constraint harms the quality of the input-output use table in a significant way. In terms of the percentage of the dollar value of materials use that is specified, this reporting constraint is not very important because in any given industry a few particular materials comprise the bulk of total materials use. The effect of this narrowness of actual use is shown in table 1 (line 1 , column 2), which notes that 97 percent of direct requirement coefficients are near zero.

Another constraint on the Census content of the use tables is that not all plants report specified materials use (table 2). For example, in the 1982 Census 72 percent of U.S. manufacturing plants were nonreporters of specified materials. However, the nonreporters tend to be the smallest plants, and this 72 percent of plants only accounted for 15 percent of the dollar value of total materials use by the manufacturing sector. Most of the nonreporters are not required to respond to questionnaires on specified materials because they are so small that the Census Bureau gathers information on their activities from the administrative records of other federal government agencies, most often tax records. Another numerous group of establishments ( 34 percent) fails to comply with the Census requests to specify materials use, but the damaging effects of this noncompliance on the quality of the use tables is held down by the fact that noncomplying establishments also tend to be small. Taken together, the lack of coverage of some materials and nonreporting by some plants results in a loss of information on about one-third of the dollar value of materials consumed by manufacturers; 67 percent of materials use is specified by kind and explicitly reported (line 7).

[^20]Despite the moderate dollar values involved in coverage problems, it is possible that the pattern of coverage of specified materials use in the Census of Manufactures biases the use table toward finding a problem of negatives under the commodity technology model. The lower rows of table 1 provide informal evidence for this latter idea that commodity technology negative requirements tend to be associated with a lack of coverage of specified materials. Remember that in the calculation of the commodity technology coefficients, $A^{c}=U V^{\prime-1}$, the weights in the averaging of use table values, $w_{k j}=v^{j k}$, are from the inverse of the transposed make table. Generally, the weights are large (and positive) for the diagonal elements of the use table, where make of the item is primary. Among the 363 large negative direct requirements coefficients, 328 are for materials that are not specified by kind in the Census reports for the primary industry (line 2, column 3 of table 1). In other words, in 90 percent of the cases of negative direct requirements, specified materials use is not available in the Census reports. This percentage is much higher than the roughly two-thirds of the large positive coefficients for which materials use is not specified by kind in the primary industry.

I have computed bounds on the effects of nonreporting on the accuracy of the aggregate use table. To explain the bounds, further notation is needed. Let $I_{i j, m}^{\text {non }}$ be an indicator variable that is one if plant $m$ is a nonreporter of specified use of material $i$ and is zero otherwise. For the purposes of calculating the bound, I assume that if specified materials use is reported at all, it is reported exactly ${ }^{2}$; i.e., if $I_{i j ; m}^{\text {non }}=0, \delta_{i j, m}=0$. Estimates of total materials use are available for all plants, so an upper bound on the unknown value of a nonreporting plant's actual use $u_{i j . m}$ is the difference between the plant's total materials use $u_{j . m}^{\text {tot }}$ and the sum of reported specified use of other materials:

$$
\begin{equation*}
u_{i j, m}^{\max }=I_{i j, m}^{\text {non }}\left(u_{. j, m}^{\text {tot }}-\sum_{p \neq i}\left(1-I_{p j, m}^{\text {non }}\right) u_{p j, m}\right)+\left(1-I_{i j, m}^{\text {non }}\right) u_{i j, m} \tag{5}
\end{equation*}
$$

For a particular industry $j$, the upper bound on the unknown use table cell is the sum across the upper bounds on the plant-level entries:

$$
\begin{equation*}
u_{i j . .}^{\max }=\sum_{m} u_{i j, m}^{\max } \tag{6}
\end{equation*}
$$

[^21]The lower bound on actual use of a nonreported material at the plant level is always zero, so at the industry level the lower bound on an unknown use table cell is the sum of reported plant-level use of the specified material:

$$
\begin{equation*}
u_{i j . .}^{\min }=\sum_{m}\left(1-I_{i j, m}^{n o n}\right) u_{i j, m} \tag{7}
\end{equation*}
$$

Let us focus on the issue of whether inaccuracy of use table cells has created negatives in the direct requirements matrix of the commodity technology model. The scalar expression for the $i j t h$ element of the direct requirements matrix $A^{c}=U V^{\prime-1}$, is

$$
\begin{equation*}
a_{i j}^{c}=\sum_{k} u_{i k . .} w_{k j} \tag{8}
\end{equation*}
$$

where the weights in the averaging of use table values, $w_{k_{j}}=\boldsymbol{v}^{\mathbf{k}}$, are from the inverse of the transposed make table. Let $I_{k j}^{w}$ be an indicator variable that is one if the weight $w_{k j}$ is positive and zero if the weight is negative. Then, for given weights $w_{k j}$, the Census records on specified materials use place the following upper bound on the $i \boldsymbol{i j h}$ element of the direct requirements matrix:

$$
\begin{equation*}
a_{i j}^{c} \max =\sum_{k} I_{k j}^{w} u_{i k . .}^{\max } w_{k j}+\left(1-I_{k j}^{w}\right) u_{i k . .}^{\min } w_{k j} \tag{9}
\end{equation*}
$$

The sign of this upper bound (9) for direct requirements entries that are negative and large in absolute value is summarized in the last row of table 1. Out of the 363 large negative entries, the Census upper bound permits reversal in 140 cases. This finding suggests that measurement error in the aggregate use tables is an important part of the problem of negatives; the amount of unknown use of materials is large enough for 39 percent of the large negative direct requirements entries to possibly be due to measurement error alone. However, measurement error likely is not the only source of the problem of negatives. In 71 percent of the cases of large negatives, the unknown amounts in cells of the use table are not large enough to eliminate the large negatives in the direct requirements matrix.

### 3.2 Heterogeneity of Use among Pure Plants

Heterogeneity of use intensities among pure plants can create negative values in commodity technology coefficients derived from aggregate make and use
tables ${ }^{3}$. For example, Rainer and Richter (1992) discuss how in the Austrian IO system a failure to distinguish between electric utilities that produce power and those that distribute power can lead to the problem of negatives. The problem is that electricity distribution facilities have a very high own input, the purchase of electricity from other establishments, which boosts the average own input for the electric utility sector as a whole. Electricity generating plants do not purchase much electricity. When electricity is made as a secondary product in other industries, the composition of intermediate inputs for electricity production in these other industries more closely mimics that of the electricity generating plants than that of the distribution facilities. Thus, the commodity technology solution on aggregate data seems to imply that there is a negative electricity requirement for the primary products of industries with large secondary production of electricity.

Let us try to discover the extent to which such heterogeneity of use intensities among plants producing only primary products is a problem in the U.S. manufacturing sector, looking beyond the electricity example. To investigate this we need technology coefficient estimates that are not contaminated by the measurement error from nonreporting discussed above. I derive technology coefficient estimates from the records for the plants that reported specified materials use, focussing on the 62,757 reporting pure plants (table 2). Notationally, a $P$ superscript denotes requirements $a_{i k m}^{P}$ from a plant $m$ in this sub-sample of pure plants. The commodity technology model, equation (1), represents the production process of multi-product plants as a linear combination of single-product technologies,

$$
\begin{equation*}
u_{i j, m}^{c}=\sum_{k} a_{i k}^{c} v_{j k m} \tag{10}
\end{equation*}
$$

and one can take the intensity of use of a material $i$ at a pure plant $m$ in industry $k$ as representative of the material requirement for the corresponding commodity, wherever produced, $a_{i \boldsymbol{i}}^{c}$. Almost all industries have some pure plants, so I am able to calculate pure-plant materials use intensities for 3754 of the 3904 material-industry combinations where use is specified by kind (last column of line 3, table 1)

[^22]Table 3 presents four statistics describing the distributions of pure-plant materials use intensities, $a_{i k m}^{P}$. First, consider the weighted average of the actual use intensities of all reporting plants in the industry, where the total product output of each plant is used as the weight. These averages, $\bar{a}_{i k m}^{P}$, are equivalent to the ratio of the total use of a given material by all pure plants in an industry to the total output of these pure plants, so the averages are analogous to the calculated commodity technology model coefficients, $a_{i k}^{c}$ from $A^{c}=U V^{r^{-1}}$, that would be derived from the standard aggregate use and make table entries, $u_{i j . .}^{0}$ and $v_{j k .}^{0}$, if there were only pure plants in the industry in question. In more than half of the cases, average consumption of the specified material among pure plants is less than one percent of output; at the 50 th quantile lies a material whose average use is .67 percent of the value of output in that industry. However, some of the averages are large; for example, in five percent of the 3754 cases, the average requirement for the material is more than 14.21 percent of output.

The distribution (across material-industry combinations) of the median (across plants) materials use intensities, $a_{i k m}^{P}$, is very skewed towards zero. This happens because for any given specified material, the Census records record that many plants in the reporting industry do not use any of the material at all. This tendency for there to be a mode at zero in specified materials use is so pronounced that more than 75 percent of the medians are zero.

Table 3 also presents two dispersion measures. The first is computed by scaling the standard deviation of the pure-plant materials use intensities $a_{i k m}^{P}$ by 1.34 , which is the interquartile range of a standard normal distribution. The second is the empirical interquartile range, the distance between the 25th and 75th quantiles of $a_{i k m}^{P}$. Many of the interquartile ranges are zero, reflecting the fact that in more than half of the material-industry reporting combinations, more than 75 percent of the plants record zero use of the specified material. Inspection of the empirical distributions of the raw data on specified materials use revealed that many were bi-modal, with a first peak at zero and a second positive peak that sometimes was quite large.

Next, let us investigate the extent to which the bi-modal distributions of reported materials use actually reflects heterogeneity of use among pure plants. This is a non-trivial effort because there is an additional reason why recorded use of specified materials might be zero: plants are told to omit listing of specified materials use if the amount used falls below a given
censoring threshold, usually 10,000 dollars. Thus, the statistics in table 3 need to be interpreted with caution because they fail to distinguish between plants that actually use none of the specified material and plants that record use of zero because the amount is rounded down to zero by censoring.

To provide a formal analysis of the effects of censoring, first consider the possibility that censoring is the only source of reporting of zero use of a specified material and that pure plants are essentially homogeneous in their materials use. I parameterize this null hypothesis by interpreting the commodity technology assumption (10), which is written as if a single coefficient $a_{i j}^{c}$ applies to all plants, as a statement about the central tendency of a (unimodal) distribution of requirements. Specifically, I assume that the logit of the actual commodity technology coefficient that applies to a particular plant $m, \log \left(a_{i j m}^{P *} /\left(1-a_{i j m}^{P *}\right)\right)$, is drawn from a normal distribution $\Phi_{i j}$ with mean $\log \left(a_{i j}^{c} /\left(1-a_{i j}^{c}\right)\right) \equiv \mu_{i j}$ and variance $\sigma_{i j}^{2}$ :
(11) $\operatorname{logit}\left(a_{i j m}^{P *}\right)-\mu_{i j} \sim \Phi_{i j}\left(0, \sigma_{i j}^{2}\right)$

A pure plant's actual use of the material is
(12) $u_{i j, m}^{*}=a_{i j m}^{P *} v_{j j m}$

The censoring constraint is that the recorded use of the material $u_{i j m}$ equals zero if the actual use $u_{i j m}^{*}$ is less than 10,000 dollars:

$$
u_{i j, m}=\begin{array}{ll}
u_{i j m}^{*} & \text { for } u_{i j m}^{*}>10,000  \tag{13}\\
0 & \text { otherwise }
\end{array}
$$

Equivalently, the observation is censored if the logit of the pure plant's actual use intensity, $\log \left(a_{i j m}^{P *} /\left(1-a_{i j m}^{P *}\right)\right)$, is below a known threshold ${ }^{4}$ :

$$
\begin{align*}
\operatorname{logit}\left(a_{i j m}^{p}\right)= & \operatorname{logit}\left(a_{i j m}^{p *}\right) \quad \text { for } \operatorname{logit}\left(a_{i j m}^{p *}\right)>\operatorname{logit}\left(10,000 / v_{j j m}\right)  \tag{14}\\
& \text { known to be censored } \quad \text { otherwise }
\end{align*}
$$

The system of equations (11)-(14) constitute a standard tobit model. To estimate the unknown parameters $\mu_{i j}$ and $\sigma_{i j}$ under this null hypothesis of homogeneity, I use the maximum-likelihood method described by Amemiya (1973). Under this null hypothesis, the maximum likelihood estimates of the

[^23]tobit model provide consistent and asymptotically efficient estimates of the unknown parameters $\mu_{i j} \sigma_{i j}$.

To formalize the alternative idea that heterogeneity of materials use among pure plants creates a problem of negatives, suppose that among the primary products of each industry there are two types of commodities, which I call low and high to denote their relative intensity of use of a specified material. The commodity technology assumption as given in (11) and (12) is assumed to be appropriate for the commodities taken individually, but the mean materials requirements for these two commodities $\mu_{i j}^{\text {low }}$ and $\mu_{i j}^{\text {high }}$ are assumed to be quite different ${ }^{5}$. Specifically, I expect that in many cases the mean $\mu_{i j}^{\text {low }}$ and dispersion $\sigma_{i j}^{\text {low }}$ parameters for the low materials use commodity are so small that it is unlikely for the censoring threshold (13) to be exceeded in samples of the size used here.

To help us relate the parameters of the null and alternative hypotheses, characterize the location of the mixture distribution by its median $\theta_{.5}$, which is the value of $a^{P}$ which exactly half of the plants are expected to fall below. Under the null hypothesis-a single type of plants with materials use requirements characterized by a censored normal distribution- the median of the uncensored normal distribution equals the mean. The interquartile range $\varsigma=\left(\theta_{.75}-\theta_{.25}\right)$ describes the dispersion of the mixture distribution. Under the null hypothesis of a non-mixed normal distribution, the scaled standard deviation $1.34 \sigma_{i j}$ equals the interquartile range. To estimate $\theta .5$ and $\varsigma$ under the alternative with heterogeneity, I employ Powell's $(1984,1986)$ Censored Least Absolute Deviations (CLAD) and Censored Regression Quantile (CRQ) estimators.

Table 4 presents the results. The estimated central location of most direct requirements distributions remains quite small with the tobit correction for censoring. For 95 percent of the material-industry combinations, the implied mean from the Tobit model is less than 2.96 percent of output. As shown in the column labelled CLAD median, the alternative estimates of location that are robust to heterogeneity generally remain well above the estimates from the tobit model. The robust estimates of dispersion tend to be quite a bit larger than the tobit estimates of dispersion, likely reflecting the ability of the

[^24]robust method to capture the wider spread of the mixture of distributions. The findings in table 4 suggest that the tobit estimates of location are biased down by heterogeneity of materials use among pure plants.

Of course, the tobit and robust estimates of location and dispersion are imprecise, so it is important to check whether the deviations of the parameter estimates are beyond the range of estimation error. The final column of table 4 presents the results of such a formal test of whether the differences between the tobit and CLAD-CRQ estimates are statistically significant, using the specification testing technique of Hausman (1978) to infer the asymptotic distribution of the difference between the estimators ${ }^{6}$. In 25 percent of the material-industry combinations, the null of homogeneity can be rejected very strongly-at the .34 percent marginal significance level. At the more conventional significance level of 5 percent, this test shows evidence of heterogeneity among pure plants for about one-third of the material-industry combinations.

## 4 Conclusion

This paper has done something different than other attempts to investigate the failure of the commodity technology model on aggregate data, such as those by ten Raa (1984), ten Raa and van der Ploeg (1989), and Rainer and Richter (1992). Measurement error in aggregate use tables was quantified not by asking compilers about the precision of their estimates, but rather by going directly to Census records from individual manufacturing plants and tabulating the effects of nonreporting. Heterogeneity of materials use among pure plants was investigated by actually looking at the empirical distributions across pure plants of materials use and by summarizing the evidence of heterogeneity in test statistics with known properties.
ten Raa (1984) and ten Raa and van der Ploeg (1989) concluded that the degree of measurement error in aggregate make and use tables cannot fully account for the problem of negatives. Although I have not overturned this conclusion by taking an extensive look at the plant-level records, what

[^25]I find striking is not that some negatives cannot be explained away on these grounds, but rather that many negatives are likely due to measurement error.

With regard to those material-industry combinations where measurement error does not appear to be a serious problem, there is broad-based evidence of heterogeneity of materials use among pure plants. Further work is needed to understand this heterogeneity and to develop ways of proceeding with IO analysis in the presence of such heterogeneity. Most such research can proceed along one of the following three lines.

First, it is possible that all variants of the Leontief technology assumption are poor approximations to the true relation between the intensity of factors of production and the level of attained output. Neoclassical economic theory certainly suggests that substitutability of capital, labor, and other materials for the specified materials could induce heterogeneity in plant-level use, and no-one has demonstrated whether or not such variations in the factor input mixes can explain the heterogeneity among pure plants that I have documented here. Data on capital and labor input for individual plants also is available in the LRD, so further research in this direction is feasible.

Second, it is possible that much of the apparent heterogeneity among plants within a given industry is due to inadequate industrial classification. The Standard Industrial Classification (SIC) system of the United States does not always give similarity of input structures primacy, partly because the system has never had a coherent, model-based rationale. Triplett (1992) and others are beginning to lay the conceptual foundation for model-based economic classification. I suspect that much of the apparent heterogeneity of materials use could be eliminated if similarity of material input structure were a more universally-applied criterion in the design of the industrial classification system. In some empirical work along these lines, Abbott and Andrews (1990) were able to devise some interesting alternative classifications.

Last, I think it is important to investigate a related problem, whether the heterogeneity among pure plants reflects what Rainer and Richter (1992) call inhomogeneity due to vertical integration. As an example, Rainer and Richter point out that among plants in the iron and steel industry group, many will engage in both the production of finished steel products and the smelting of iron ore. If the latter commodity (smelted ore) is produced and consumed within the same establishment, the vertically integrated plant still appears to be pure in the sense that the produced and consumed item does not appear as a secondary product in published statistics. Yet, the mix
of purchased inputs in the vertically-integrated plant is going to be very different from that in non-integrated plants.

It is clear that vertical integration within plants exists. Further research is needed to document the extent of vertical integration within plants and to explain why some plants choose to integrate and others do not. In his recent Nobel lecture, R.H. Coase (1992) singled out the work at the Center for Economic Studies (CES) as especially important to further understanding the activities of firms. This paper uses the data available at the CES to provide clear evidence of heterogeneity among plants that appear to be similar by conventional classification measures. It remains to be seen whether the theory of the firm can explain this heterogeneity as a natural outcome of the forces that lead to vertical integration within plants.

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Table 1

> Size of Commodity Technology Direct Requirements for Manufactured Goods as Calculated from the U.S. IO Accounts for $1982^{a}$

$$
\text { (number of entries by size }{ }^{b} \text { ) }
$$

|  | Large Positive | Near Zero | Large Negative | Total |
| :---: | :---: | :---: | :---: | :---: |
| 1. All commodities | $\begin{gathered} 4668 \\ (2.35) \end{gathered}$ | $\begin{aligned} & 193,659 \\ & (97.47) \end{aligned}$ | $\begin{gathered} 363 \\ (.18) \end{gathered}$ | $\begin{aligned} & 198,690 \\ & (100.00) \end{aligned}$ |
| By reporting of material in primary industry |  |  |  |  |
| 2. Not specified by kind in Census | $\begin{gathered} 3099 \\ (1.56) \end{gathered}$ | $\begin{aligned} & 191,359 \\ & (96.31) \end{aligned}$ | $\begin{gathered} 328 \\ (.17) \end{gathered}$ | $\begin{aligned} & 194,786 \\ & (98.04) \end{aligned}$ |
| 3. Specified by kind in Census | $\begin{gathered} 1569 \\ (.79) \end{gathered}$ | $\begin{gathered} 2300 \\ (1.16) \end{gathered}$ | $\begin{gathered} 35 \\ (.02) \end{gathered}$ | $\begin{gathered} 3904 \\ (1.96) \end{gathered}$ |
| 4. Scrap | $\begin{gathered} 13 \\ (.01) \end{gathered}$ | $\begin{gathered} 57 \\ (.03) \end{gathered}$ | $\begin{gathered} 22 \\ (.01) \end{gathered}$ | $\begin{gathered} 92 \\ (.05) \end{gathered}$ |
| 5. Other | $\begin{gathered} 1556 \\ (.78) \end{gathered}$ | $\begin{gathered} 2243 \\ (1.13) \end{gathered}$ | $\begin{gathered} 13 \\ (.01) \end{gathered}$ | $\begin{gathered} 3812 \\ (1.92) \end{gathered}$ |
| Memo: <br> 6. Census upper bound permits reversal ${ }^{\text {c }}$ |  |  | $\begin{array}{r} 140 \\ (39) \end{array}$ |  |

## Source: Calculations by the author.

a. For the purposes of this table's grouping by sise, large means greater than one percent of output.
b. Numbers in parentheses are the percent of total entries in that category.
c. See the text for the definition of the upper bound.

Table 2
Coverage of Specified Materials Use in the 1982 Census of Manufactures

|  | Number of <br> Plants | Percent | Amount of <br> Materials ${ }^{\text {a }}$ | Percent |
| :--- | :---: | :---: | :---: | :---: |

## Source: Calculations by the author.

a. Millions of dollars of materials purchased and consumed. Excludes materials produced and consumed.
b. For plant in industries asked to report specified materials use, includes non-administrative-record plants with materials use explicitly coded as n.s.k. and plants with only a positive balancing record in the detailed materials records.
c. Also includes some unknown amount of materials of the types specified by kind but not reported under specified materials because the amount consumed was less than a censoring threshold, typically 10,000 dollars.
d. Pure plants have IO basis primary product specialisation ratios less than unity and less than half of total receipts from miscellaneous activities.

Table 3
Distribution of Direct Requirements for Specified Materials
from Reporting Pure Plants
in the 1982 U.S. Census of Manufactures
(material consumption as a percent of output)

|  | Statistic summarizing |  | $A^{p}$ distribution |  |
| :---: | :---: | :---: | :---: | :---: |
|  | Location parameters |  | Dispe | n Measures |
| Quantile of Statistic | Weighted <br> Average | Median | Scaled <br> Standard <br> Deviation | Interquartile Range |
| 0 | . 00 | . 00 | . 00 | . 00 |
| 5 | . 01 | . 00 | . 10 | . 00 |
| 25 | . 17 | . 00 | . 86 | . 00 |
| 50 | . 67 | . 00 | 2.58 | . 00 |
| 75 | 2.26 | . 00 | 7.15 | 1.43 |
| 95 | 14.21 | 7.22 | 24.19 | 16.70 |
| 100 | 90.00 | 90.03 | 55.07 | 94.38 |

There are 3754 observations on each statistic, one observation per material-industry combination with reports of specified materials use available from pure plants.

Table 4
Distribution of Direct Requirements for Specified Materials
from Reporting Pure Plants
after Controlling for Censoring
(material consumption as a percent of output) ${ }^{a}$

a. There are 3751 observations on each statistic, one observation per material-industry combination with reports of specified materials use available from more than one pure plant. Estimation and testing was done on the logits of the observed shares, so the location parameters shown here were calculated by applying the inverse logit transformation to the estimated parameters. The interquartile ranges were transformed similarly.
b. The entries in this column are the quantiles for the marginal significance levels of the Hausman specification test, in percent.

## WORKING PAPER

## SOCIAL ACCOUNTS AND THE STRUCTURE OF THE NORTH AMERICAN ECONOMY

by

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# Social Accounts and the Structure of the North American Economy 

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#### Abstract

This paper presents the methodology for and results of the construction of a 26 -sector social accounting matrix (SAM) for North America. We begin with the construction of three macroeconomic SAMs and their integration into a North Amercian macroeconomic SAM. We then turn to the construction of a sectorally detailed SAM for the continent. Finally, we consider the structure of North American receipts and payments and the regional decomposition of multipliers.


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# Social Accounts and the Structure of the North American Economy 

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## I. INTRODUCTION

As Richard Stone stated in his Nobel Prize lecture (1986), any modeling excercise rests on theories and facts. With regard to the analysis of the North American economy, theory is supplied by multicountry, calibrated general equilibrium (CGE) models involving production, consumption, and trade components. During the 1980s, such models were constructed to analyze the U.S.-Canada free trade area and were reviewed by Coughlin (1990). Recently, new CGE models have emerged to analyze trade among all three North American countries, especially the effects of a North American Free Trade Area (NAFTA). These models have been reviewed in U.S. International Trade Commission (1992) and Brown (1992). In this paper, we addressed the question of economic facts in North America. Specifically, we undertake the organization of economic data for the continent into a convenient and consistent form known as a social accounting matrix (SAM). The North American SAM details 26 production sectors and is consistent with the macroeconomic accounts for the three countries.

The arrangement of national economic accounts in a matrix format is now familiar, an important early source being the United Nations System of National Accounts (UNSO, 1968). An early application of the SAM framework was in the area of development planning where it was used as a foundation for multiplier analysis (e.g., Pyatt and Round, 1977 and 1979). Since this early work, SAMs have become instrumental in the calibration of CGE models (Dervis, de Melo, and Robinson, 1982 and Reinert and Roland-Holst, 1992b).

While most work on SAMs has been at the single-country level, CGE analysis of the North American economy requires a multicountry framework. The intellectual origins of multicountry SAMs can be traced back to Stone (1961) who applied matrix accounts to

[^26]subnational regions, and this work has since been enriched by Round (1985 and 1991) and others. A related effort in the North American context is the work of Burfisher and Thierfelder (1992) on a U.S.-Mexico SAM with agricultural detail.

The following section describes the construction of a North American macroeconomic SAM from individual country macroeconomic SAMs. Section III describes the construction of the detailed North American SAM with 26 production sectors. Section IV takes a brief look at the structure of receipts and expenditures in the North American economy, and Section V considers the regional decomposition of multipliers. Finally, Section VI presents some concluding comments.

## II. A NORTH AMERICAN MACROECONOMIC SAM

Construction of the North American SAM began with the transformation of 1988 national accounts for each country into three separate macroeconomic SAMs. ${ }^{2}$ These macroeconomic SAMs are constructed with 13 accounts denoted by 6 -letter labels. The first three letters denote the country ("can", "usa", and "mex"), and the last three letters denote the specific account type. The activity accounts ("act") purchase factor inputs to produce commodities. ${ }^{3}$ The commodity accounts ("com") combine domestic supply with imports. There are two types of factor accounts: labor ("lab") and property ("pro"). The enterprise accounts ("ent") collect gross profits and government transfers and distribute them to other accounts. The household accounts ("hld") receive income from the labor, enterprise, and other accounts, the bulk of expenditures being on commodities in the form of final demand. The value added tax accounts ("vat") have positive entries only in the case of Mexico. The government accounts ("gov") collect tax revenue from a variety of sources. As with the household account, the bulk of expenditures are on commodities. The capital accounts ("cap") close the system of income expenditure flows in each country, channeling savings into demand for investment commodities.

The rest of the world accounts ("row") record international transactions, and the tariff accounts ("tar") register tariff revenues by sector of collection and distribute them to the government accounts. Tariffs are recorded separately from other commodity taxes to aid in the calibration of tax instruments in general equilibrium models. Official errors are recorded in an error account ("err"), and totals are given in final accounts ("tot").

The Canadian macroecononic SAM was constructed from data presented in Statistics Canada (March 1991 and April 1991) and is presented in Table 1. The U.S. macroeconomic SAM was taken from Reinert and Roland-Holst (1992a) and is presented in Table 2. The Mexican macroeconomic SAM was constructed from data presented in Estados Unidos Mexicanos (1990) and is presented in Table 3. The Mexican macroeconomic SAM lacks some of the interinstitutional detail present in the Canadian and U.S. macroeconomic SAMs due to lack of consistent three country data.

Next, the individual macroeconomic SAMs were joined together into a North American macroeconomic SAM. This process entailed three separate steps. First, the Canadian

[^27]and Mexican macroeconomic SAMs were converted to 1988 U.S. dollars at 1.23 Canadian dollars per U.S. dollar and $2,273.1$ pesos per U.S. dollar, respectively. These rates are yearly averages of market exchange rates from the International Monetary Fund, International Financial Statistics. As Stone (1986) notes, "exchange rates do not necessarily reflect purchasing power" (p. 20). An alternative conversion factor would be purchasing power parities (PPPs). Data from Summers and Heston (1991) indicate a PPP for Mexico of 893.3, which would lead to substantially larger values for the Mexican economy in the North American SAM. However, it is not clear that PPPs are appropriate for all components of SAMs, and different PPPs would need to be used for different components. This remains an important issue for further consideration.

Second, trade flows between each of the countries were added to the multicountry SAM and subtracted from the rest of the world account. Data on total U.S. trade with Mexico and Canada were taken from U.S. Department of Commerce (1988). Data on total trade between Canada and Mexico were taken from Globerman and Bader (1991). Total Mexican trade was adjusted for maquiladora trade, since these activities are not reflected in the Mexican national accounts. The maquiladora trade was estimated based on data from U.S. International Trade Commission (1991). ${ }^{4}$ Third, factor service flows and capital flows between the three countries were added with the appropriate subtractions from the rest of the world account. These flow data were obtained from U.S. Department of Commerce (1991). The resulting North American macroeconomic SAM is presented in Table 4.

## III. A DETAILED NORTH AMERICAN SAM

The second stage in the construction of the North American SAM involved estimation of detailed sectoral accounts. The detailed accounts were built upon 26 comparable sectors for each economy. This sectoring scheme, presented in Table 5, was based on Sobarzo (1992). A modified macroeconomic SAM was used to provide control totals for the detailed accounts. This modification resulted in a macroeconomic SAM different in two respects from that presented in Table 4. First, the activity accounts were removed using the consolidation procedure described by Pyatt (1985). Second, the household, government, and capital accounts were added together to form a single final demand account. ${ }^{5}$

The general procedure used in constructing the detailed accounts was to disaggregate transactions in the modified macroeconomic SAM that are part of the commodity row or column. These inclucle value added, domestic final demand, import, export, and interindustry transactions. We consider each in turn.

For each country, control totals were taken from the macroeconomic SAM for labor, property, and indirect business tax components of value added. For Canada, these three

[^28]control totals were distributed across the 26 sectors based on shares from the 1988 inputoutput accounts of the Canadian economy. For the United States, sectoral value added for each of the three components could be taken directly from Reinert and Roland-Holst (1992a). For Mexico, the three control totals were distributed across the 26 sectors based on total 1988 sectoral value added information from Estados Unidos Mexicanos (1990) and 1985 value added by component from Sobarzo (1992).

The controi totals for domestic final demand for each country were taken from the macroeconomic SAM. For Canada, the control total was distributed across the 26 sectors based on shares from the 1988 input-output accounts of the Canadian economy. For the United States, the sectoral domestic final demands were taken directly from Reinert and Roland-Holst (1992a). For Mexico, sectoral domestic final demands were estinated based on 1985 shares from Sobarzo (1992).

Sectoral trade flows were estimated based on U.S. import data from the U.S. Department of Commerce and 3 -digit SITC trade data from the United Nations. A Canadian import submatrix was estimated based on the 3 -digit SITC data and then balanced to control totals from the macroeconomic SAM using the RAS matrix balancing procedure.
6 A Canadian export submatrix was then estimated in a similar manner using 3 -digit SITC data as well as data on U.S. imports from Canada taken from U.S. Department of Commerce data tapes. U.S. imports from Mexico by sector also were taken from the U.S. Department of Commerce data tapes. U.S. imports from the rest of the world by sector were then calculated as a residual. Mexican innports from the United States were taken from the U.N. 3-digit SITC data.

With regard to interindustry transactions, Canadian interindustry flows required negligible rebalancing to row and column controls calculated from the new sectoral data. U.S. interindustry flows were taken directly from Reinert and Roland-Holst (1992a). Mexican interindustry flows were updated from 1985 based on row and column controls calculated from the estimated 1988 sectoral data using the RAS procedure.

It is impractical to display the detailed three-country SAM in this paper. Instead, we present an aggregated version in Table 6. In this version of the SAM, there are four commodity accounts: a primary sector consisting of agriculture, mining, and petroleum; a manufacturing sector; a construction sector; and a service sector. One feature of Table 6 worth highlighting is the entries in the intercountry submatrices. These entries consist of trade flows, direct foreign investment flows, and transfers. An example of a trade flow is transaction (usamanuf,canmanuf) which records US $\$ 65,113$ million in manufactured imports by Canada from the United States. In contrast, Canada's imports of manufactured goods from Mexico given in transaction (nexmanuf, canmanuf) amounted to only US $\$ 851$ million in 1988. An example of a direct foreign investment flow is transaction (usapro,canpro). This is a payment by Canada to the United States of US\$7,247 million for U.S. capital service exports. An example of a transfer payment is transaction (usadfd,mexdfd) which records a US $\$ 4,661$ million transfer by Mexico to the United States.

[^29]
## IV. THE STRUCTURE OF THE NORTH AMERICAN ECONOMY

While the nominal flows in a SAM are of some interest in themselves, the structure of economic linkages in North America can be seen more clearly with some simple share calculations. Table 7 gives the composition of expenditures for each of the 78 production sectors of the North American SAM. Each entry in this table gives the share of the indicated column account's total expenditures on the indicated row account. This information is useful for identifying upstream effects of changes in column-sector final demands.

One feature inmediately obvious from Table 7 is the relatively weak trade linkages between Canada and Mexico. All expenditure shares of the Canadian commodity accounts on Mexican commodities are less than 1 percent. The same is true of Mexican commodity account expenditures on the Canadian commodity accounts.

Expenditure shares of Canadian commodity accounts on U.S. commodity accounts are much larger than those on Mexican commodity accounts. For Canadian nonelectrical machinery, electrical machinery, and transportation equipment accounts, expenditure shares on corresponding U.S. accounts exceed 20 percent. Similarly, expenditure shares of Mexican commodity accounts on U.S. commodity accounts are much larger than those on Canadian commodity accounts. For Mexican nonelectrical machinery and electrical machinery accounts, expenditure shares on corresponding U.S. accounts exceed 40 percent.

These observations document the hub-and-spoke structure of North American trade, with the United States playing the role of a hub. The highest expenditure shares of U.S. commodity accounts on Canadian commodity accounts occur in paper, nonferrous metals, and transportation equipment. The highest expenditure shares of U.S. commodity accounts on Mexican commodity accounts occur in petroleun, leather products, and electrical machinery. In most cases, however, U.S. expenditure shares on the rest of the world account exceed those on corresponding Canadian and Mexican commodity accounts. This indicates that the United States is less dependent than either of its neighbors on the North American economy.

Table 7 also provides expenditure shares corresponding to interindustry transactions. These are the three 26 by 26 matrices with commodity accounts of the country in question. As expected, the United States displays the most dense interindustry matrix with a coefficient total of 12.4. Canada and Mexico have equal density with a coefficient total of 10.0 .

Downstream effects or forward linkages can be seen in Table 8, where each column corresponds to a normalized row of the North American SAM and gives the percentage composition of deliveries for each sector's output to intermediate al I final use. As expected, Canadian receipt shares from Mexico are very small. Those Canadian commodity accounts with the largest receipt shares from the United States are petroleum, paper, nonferrous metals, and trensportation equipment. U.S. receipt shares from Mexico are also small, those exceeding one percent being leather, nonelectrical machinery, and electrical machinery. The U.S. commodity accounts with the largest receipt shares from Canada are mining, nonelectrical machinery, and transportation equipment. In most cases, however, U.S. receipt shares from the rest of the world account exceed those from corresponding Canadian and Mexican commodity accounts. Again, this indicates that the United States is less dependent than Canada and Mexico on the North American economy.

Canada does have importance to Mexico from the point of view of Mexico's receipts. These exceed 1 percent for mining, nonelectrical machinery, electrical machinery, transportation equipment, and other manufacturing. Of course, the United States is more significant than Canada from the point of view of Mexican receipts. Mexican commodity accounts where receipts from the United States are greater than 10 percent are petroleum, apparel, rubber and plastic products, nonferrous metals, wood and metal products, electrical machinery, transportation equipment, and other manufactured products. Also notable is the Mexican petroleum products receipt share from the rest of the world of 44 percent.

Tables 7 and 8 reveal the United States as the center or hub of the North American economy, with relatively few strong links between Mexico and Canada. However, the United States is less dependent in its trade relations than either of its neighbors on the North American economy. Overall, North American interdependence is strongest in the machinery and transportation equipment sectors. We will explore these interdependencies further in the following section.

## V. THE REGIONAL DECOMPOSITION OF MULTIPLIERS

Social accounting matrices are rarely built for their own sake, but instead are used to conduct analysis of the economic units whose linkages are tabulated in the SAM. In the present case, the SAM was constructed primarily for analyzing a North American Free Trade Area (NAFTA) using a calibrated general equilibrium model. ${ }^{7}$ The North American SAM also lends itself to the application of multiplier analysis as will be seen below. ${ }^{8}$

For analytical purposes, define the full North American SAM as the matrix S. The row sums of $S$ yield a column vector of incomes, denoted $y$. Column normalization of $S$ yields the matrix of expenditure shares, denoted $\mathbf{A}$. The fact that the column and row sums of $S$ are equal for corresponding accounts leads to the following well-known identity:

$$
\begin{equation*}
\mathbf{y}=\mathbf{A y} \tag{1}
\end{equation*}
$$

Now consider a partition of the accounts into $m$ endogenous accounts and $k$ exogenous accounts. Equation 1 now takes the form:

$$
\binom{\mathbf{y}_{m}}{\mathbf{y}_{k}}=\left(\begin{array}{cc}
\mathbf{A}_{m m} & \mathbf{A}_{m k}  \tag{2}\\
\mathbf{A}_{k m} & \mathbf{A}_{k k}
\end{array}\right)\binom{\mathbf{y}_{m}}{\mathbf{y}_{k}}
$$

Endogenous incomes are expressed as:

$$
\begin{align*}
\mathbf{y}_{m} & =\mathbf{A}_{m m} \mathbf{y}_{m}+\mathbf{A}_{m k} \mathbf{y}_{k} \\
& =\mathbf{A}_{m m} \mathbf{y}_{m}+\mathbf{x} \tag{3}
\end{align*}
$$

[^30]where $\mathbf{x}$ is a $m \times 1$ vector of exogenous injections.
Now partition the matrix $\mathbf{A}_{m m}$ by country, where the subscripts 1,2 , and 3 denote Canada, the United States, and Mexico, respectively. This leads to the following equation for endogenous incomes in North America:
\[

\left($$
\begin{array}{l}
\mathbf{y}_{1}  \tag{4}\\
\mathbf{y}_{2} \\
\mathbf{y}_{3}
\end{array}
$$\right)=\left($$
\begin{array}{lll}
\mathbf{A}_{11} & \mathbf{A}_{12} & \mathbf{A}_{13} \\
\mathbf{A}_{21} & \mathbf{A}_{22} & \mathbf{A}_{23} \\
\mathbf{A}_{31} & \mathbf{A}_{32} & \mathbf{A}_{33}
\end{array}
$$\right)\left($$
\begin{array}{l}
\mathbf{y}_{1} \\
\mathbf{y}_{2} \\
\mathbf{y}_{3}
\end{array}
$$\right)+\left($$
\begin{array}{l}
\mathbf{x}_{1} \\
\mathbf{x}_{2} \\
\mathbf{x}_{3}
\end{array}
$$\right)
\]

The matrix $\mathbf{A}_{\boldsymbol{m} \boldsymbol{m}}$ can be additively decomposed as:

$$
\begin{aligned}
\mathbf{A}_{m m} & =\left(\begin{array}{ccc}
\mathbf{A}_{11} & 0 & 0 \\
0 & \mathbf{A}_{22} & 0 \\
0 & 0 & \mathbf{A}_{33}
\end{array}\right)+\left(\begin{array}{ccc}
0 & \mathbf{A}_{12} & \mathbf{A}_{13} \\
\mathbf{A}_{21} & 0 & \mathbf{A}_{23} \\
\mathbf{A}_{31} & \mathbf{A}_{32} & 0
\end{array}\right) \\
& =\mathbf{B}+\mathbf{C}
\end{aligned}
$$

This leads to a reduced-form version of equation (3):

$$
\begin{align*}
\mathbf{y}_{m} & =\mathbf{B} \mathbf{y}_{m}+\mathbf{C} \mathbf{y}_{m}+\mathbf{x} \\
& =(\mathbf{I}-\mathbf{B})^{-1} \mathbf{C} \mathbf{y}_{m}+(\mathbf{I}-\mathbf{B})^{-1} \mathbf{x} \\
& =\left[\mathbf{I}-(\mathbf{I}-\mathbf{B})^{-1} \mathbf{C}\right]^{-1}(\mathbf{I}-\mathbf{B})^{-1} \mathbf{x} \\
& =(\mathbf{I}-\mathbf{D})^{-1}(\mathbf{I}-\mathbf{B})^{-1} \mathbf{x} \tag{5}
\end{align*}
$$

where $\mathbf{D}=(\mathbf{I}-\mathbf{B})^{-1} \mathbf{C}$.
The result is a product decomposition of multiplier matrices of the form:

$$
\begin{equation*}
\mathbf{y}_{m}=\mathbf{M}_{2} \mathbf{M}_{1} \mathbf{x} \tag{6}
\end{equation*}
$$

where $\mathbf{M}_{1}=(\mathbf{I}-\mathbf{B})^{-1}$ and $\mathbf{M}_{2}=(\mathbf{I}-\mathbf{D})^{-1}$.
Upon closer inspection, the first multiplier matrix $\mathbf{M}_{1}$ can be written out in terms of expenditure shares as:

$$
M_{1}=\left(\begin{array}{ccc}
\left(\mathrm{I}-\mathbf{A}_{11}\right)^{-1} & 0 & 0 \\
0 & \left(\mathrm{I}-\mathbf{A}_{22}\right)^{-1} & 0 \\
0 & 0 & \left(\mathrm{I}-\mathbf{A}_{33}\right)^{-1}
\end{array}\right)
$$

This matrix is a block diagonal array of intra-country multiplier matrices. Since any additional multiplier eifects involve matrix $\mathbf{C}$, matrix $\mathrm{M}_{1}$ corresponds to the multipliers which would be obtained from three single-country SAMs studied in isolation.
$\mathbf{M}_{\mathbf{2}}$ can be written out in terms of expenditure shares as:

$$
\mathbf{M}_{2}=\left(\begin{array}{ccc}
\mathbf{I} & -\left(\mathrm{I}-\mathbf{A}_{11}\right)^{-1} \mathbf{A}_{12} & -\left(\mathrm{I}-\mathbf{A}_{11}\right)^{-1} \mathbf{A}_{13} \\
-\left(\mathrm{I}-\mathbf{A}_{22}\right)^{-1} \mathbf{A}_{21} & \mathbf{I} & -\left(\mathbf{I}-\mathbf{A}_{22}\right)^{-1} \mathbf{A}_{23} \\
-\left(\mathrm{I}-\mathbf{A}_{33}\right)^{-1} \mathbf{A}_{31} & -\left(\mathrm{I}-\mathbf{A}_{33}\right)^{-1} \mathbf{A}_{32} & \mathbf{I}
\end{array}\right)^{-1}
$$

Since matrix $\mathbf{M}_{1}$ fully accounts for intra-country multiplier effects, $\mathbf{M}_{\mathbf{2}}$ accounts for the remainder of the total multiplier effects. These are inter-country effects the size of which depend on the elements of matrix C .

Equation (6) can be rewritten as:

$$
\begin{align*}
\mathbf{y}_{m} & =\left[\mathbf{I}+\left(\mathbf{M}_{1}-\mathbf{I}\right)+\left(\mathbf{M}_{2}-\mathbf{I}\right) \mathbf{M}_{1}\right] \mathbf{x} \\
& =\left(\mathbf{I}+\mathbf{N}_{1}+\mathbf{N}_{2}\right) \mathbf{x} \tag{7}
\end{align*}
$$

This is an additive multiplier decomposition. It begins with the effects of the injection itself (the matrix I). The matrix $\mathbf{N}_{1}=\left(\mathbf{M}_{1}-\mathbf{I}\right)$ gives the contributions of intra-country effects net of the effects of the injection itself. The matrix $\mathbf{N}_{2}=\left(\mathbf{M}_{2}-\mathbf{I}\right) \mathbf{M}_{1}$ gives the contributions of inter-country effects net of the intra-country effects.

In implementing the above multiplier analysis, one must first decide which accounts are to be treated as endogenous and which are to be treated as exogenous. We follow Pyatt and Round (1979) in assuming that the commodity accounts, value added accounts, and the enterprise accounts are endogenous. Pyatt and Round assume that the household account is endogenous, while the government and capital accounts are exogenous. In our SAM, these accounts are aggregated into three domestic final demand accounts, one for each country. For this reason, we first treat the domestic final demand accounts as exogenous in what we refer to as Multiplier Analysis I and then as endogenous in Multiplier Analysis II. Finally, we follow Pyatt and Round in assuming that the rest of the world account, the tariff accounts, and the value added tax account are exogenous.

In Multiplier Analysis I, injections include transfers to enterprises by the domestic final demand accounts and profit incomes by the property accounts from the rest of the world account, as well as demand for commodities by both the domestic final demand and rest of the world accounts. Leakages under Multiplier Analysis I include direct and indirect taxes, savings, imports, and profit expenditures by property accounts to the rest of the world. Under Multiplier Analysis II, injections include profit incomes by the property accounts and demand for commodities, both from the rest of the world account. Leakages include import expenditures by the commodity accounts and profit expenditures by property accounts, both to the rest of the world. In Multiplier Analysis II, the income-expenditure links of the three domestic final demand accounts are endogenous, leading to higher multiplier values. Multiplier Analysis II therefore provides upper-bound multipliers in contrast to the lowerbound multipliers of Multiplier Analysis I which exclude the endogenous domestic demand effects. ${ }^{9}$

Table 9 presents the merchandise diagonal elements of the off-diagonal submatrices of the inter-country matrix $\mathbf{N}_{2}$ for Multiplier Analysis I. The off-diagonal submatrices also have nonzero off-diagonal elements, but we ignore them here for brevity. The column heading $N_{2}(i j)$ in Table 9 denotes the additive inter-country multiplier effect in cents on income of the row sector in region $i$ per dollar increase in exogenous demand for the row sector in region $j$.

[^31]Column $N_{2}$ (12) gives the multiplier effects of changes in U.S. final demand on incomes in Canada. Overall the multipliers are relatively small, a reflection of diversified U.S. import sources noted in Section IV above. The largest linkage is for transportation equipment, followed by petroleum, paper products, and nonferrous metals. Column $\mathrm{N}_{2}(13)$ gives the multiplier effects of changes in Mexican final clemand on incomes in Canada. These are even smaller than those of the first column. The largest linkages occur in the transportation equipment, paper product, and nonelectrical machinery sectors.

Column $\mathrm{N}_{2}(21)$ gives the multiplier effects of changes in Canadian final demand on incomes in the United States. These multipliers tend to be large, reflecting a high propensity to import from the United States on the part of Canada. The largest linkages occur in nonelectrical machinery and transportation equipment. Other strong linkages exist in textiles, chemicals, rubber and plastic products, nonferrous metals, and electrical machinery. Column $\mathrm{N}_{2}(23)$ gives the multiplier effects of changes in Mexican final demand on incomes in the United States. These are also relatively large, again reflecting a high propensity to import from the United States. Here, the largest linkages are in nonelectric and electric machinery, followed by rubber and plastic products, paper products, and nonferrous metals.

Columns $\mathrm{N}_{2}(31)$ and $\mathrm{N}_{2}(32)$ give the multiplier effects of changes in Canadian and U.S. final demands, respectively, on incomes in Mexico. These multipliers tend to be relatively small and reflect low propensities to import from Mexico. In the case of Canadian final clemand, the strongest linkages are in mining, nonelectrical machinery, and electrical machinery. In the case of U.S. final demand, the strongest linkages are in petroleum, leather, nonferrous metals, electrical machinery, and transportation equipment.

Table 10 presents the merchandise diagonal elements of the off-diagonal submatrices of the matrix $\mathrm{N}_{2}$ for Multiplier Analysis II. With regard to the structure of linkages in the North American economy, Table 10 presents information analogous to that presented in Table 9. In Multiplier Analysis II, however, all domestic final demand is endogenous. For this reason, the multipliers in Table 10 should be interpreted as upper-bound multipliers. Each entry in Table 10 is larger than the corresponding entry in Table 9. There is also a tendency for the sectoral ordering of the magnitudes of each intercountry multiplier to remain the same between the two tables. However, in many instances, the inclusion of endogenous domestic demand effects in Table 10 changes the sectoral ordering somewhat. As an example, take the agricultural sector entry of $\mathrm{N}_{2}(32)$. This gives the income effect on Mexican agriculture of changes in exogenous demand for agriculture in the United States. In Table 9, this multiplier ranks sixth (tied with other manufacturing) among the 20 nonservice sectors. In Table 10, the multiplier ranks third, moving ahead of nonferrous metals and transportation equipment. Readers with specific sectoral interests will want to compare Tables 9 and 10 carefully.

Overall, the inter-country multiplier analysis reveals strong interdependence in nonferrous metals, nonelectrical machinery, electrical machinery, and transportation equipment. Despite the hub-and-spoke nature of the North American economy alluded to above, some of these linkages are significant between the Canadian and Mexican economies.

## VI. CONCLUDING COMMENTS

Social accounting matrices provide a comprehensive and consistent means of organizing data on single or multiple economies. They are of interest in themselves, allowing the analyst to identify the important structural features of the economies under consideration. SAMs also play an indispensable role in calibrating modern simulation models. Despite the early precedent set by multiregional input-output modeling, there have been few applications of SAMs in a multicountry context.

Inspired by recent interest in North American economic integration, this paper reported on the construction of a North American SAM for 1988. We began with the transformation of the macroeconomic accounts of the three countries into a North American macroeconomic SAM and then turned to the construction of a sectorally-detailed SAM. Row and column normalizations and multiplier decompositions permitted analysis of the broad structural features of the North American economy.

One question raised in this work is the choice of a conversion factor for the Mexican accounts into U.S. dollars. We relied on the exchange rate, but purchasing power parity would have yielded substantially different results. This issue will arise in all multicountry SAMs which include countries at significantly different levels of economic development. Further work also might be conducted in the area of environmental accounting, given the importance of environmental issues in the North American context. ${ }^{10}$

[^32]
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Table 1: Macroeconomic SAM for Canada, 1988 (millions of Canadian dollars)

|  | canact | cancom | canlab | canpro | canent | canhld |
| ---: | ---: | ---: | ---: | ---: | ---: | ---: |
| canact | 0 | 598,836 | 0 | 0 | 0 | 0 |
| cancom | 0 | 0 | 0 | 0 | 0 | 350,624 |
| canlab | 328,562 | 0 | 0 | 0 | 0 | 0 |
| canpro | 210,576 | 0 | 0 | 0 | 0 | 0 |
| canent | 0 | 0 | 0 | 191,694 | 0 | 6,077 |
| canhld | 0 | 0 | 300,366 | 0 | 119,084 | 0 |
| canvat | 0 | 0 | 0 | 0 | 0 | 0 |
| cangov | 60,685 | 0 | 28,196 | 0 | 58,632 | 83,421 |
| cancap | 0 | 0 | 0 | 0 | 73,342 | 50,968 |
| canrow | 0 | 154,299 | 0 | 30,201 | 0 | 799 |
| cantar | 0 | 4,520 | 0 | 0 | 0 | 0 |
| canerr | -987 | 0 | 0 | 0 | 0 | 0 |
| cantot | 598,836 | 757,655 | 328,562 | 221,895 | 251,058 | 491,889 |


|  | canvat | cangov | cancap | canrow | cantar | canerr | cantot |
| :---: | ---: | ---: | ---: | ---: | ---: | ---: | ---: |
| canact | 0 | 0 | 0 | 0 | 0 | 0 | 598,836 |
| cancom | 0 | 113,295 | 134,019 | 158,731 | 0 | 986 | 757,655 |
| canlab | 0 | 0 | 0 | 0 | 0 | 0 | 328,562 |
| canpro | 0 | 0 | 0 | 11,319 | 0 | 0 | 221,895 |
| canent | 0 | 53,287 | 0 | 0 | 0 | 0 | 251,058 |
| canhld | 0 | 71,597 | 0 | 842 | 0 | 0 | 491,889 |
| canvat | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| cangov | 0 | 0 | 3,499 | 1,670 | 4,520 | 0 | 240,623 |
| cancap | 0 | 0 | 0 | 15,181 | 0 | -987 | 138,504 |
| canrow | 0 | 2,444 | 0 | 0 | 0 | 0 | 187,743 |
| cantar | 0 | 0 | 0 | 0 | 0 | 0 | 4,520 |
| canerr | 0 | 0 | 986 | 0 | 0 | 0 | -1 |
| cantot | 0 | 240,623 | 138,504 | 187,743 | 4,520 | -1 |  |

Table 2: Macroeconomic SAM for the United States, 1988 (millions of U.S. dollars)

|  | usaact | usacom | usalab | usapro | usaent | usahld |
| :--- | ---: | ---: | ---: | ---: | ---: | ---: |
| usaact | 0 | $4,830,868$ | 0 | 0 | 0 | 0 |
| usacom | 0 | 0 | 0 | 0 | 0 | $3,235,095$ |
| usalab | $2,907,647$ | 0 | 0 | 0 | 0 | 0 |
| usapro | $1,555,756$ | 0 | 0 | 0 | 0 | 0 |
| usaent | 0 | 0 | 0 | $1,589,072$ | 0 | 96,146 |
| usahld | 0 | 0 | $2,463,048$ | 0 | $1,045,732$ | 0 |
| usavat | 0 | 0 | 0 | 0 | 0 | 0 |
| usagov | 377,065 | 0 | 444,599 | 0 | 137,936 | 586,649 |
| usacap | 0 | 0 | 0 | 0 | 593,842 | 144,711 |
| usarow | 0 | 537,900 | 0 | 83,431 | 0 | 1,862 |
| usatar | 0 | 16,448 | 0 | 0 | 0 | 0 |
| usaerr | $-9,600$ | 0 | 0 | 0 | 0 | 0 |
| usatot | $4,830,868$ | $5,385,216$ | $2,907,647$ | $1,672,503$ | $1,777,510$ | $4,064,463$ |


|  |  | usavat | usagov | usacap | usarow | usatar | usaerr |
| ---: | ---: | ---: | ---: | ---: | ---: | ---: | ---: |
| usaact | 0 | 0 | 0 | 0 | 0 | 0 | $4,830,868$ |
| usacom | 0 | 968,946 | 750,257 | 430,918 | 0 | 0 | $5,385,216$ |
| usalab | 0 | 0 | 0 | 0 | 0 | 0 | $2,907,647$ |
| usapro | 0 | 0 | 0 | 116,747 | 0 | 0 | $1,672,503$ |
| usaent | 0 | 92,292 | 0 | 0 | 0 | 0 | $1,777,510$ |
| usahld | 0 | 555,683 | 0 | 0 | 0 | 0 | $4,064,463$ |
| usavat | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| usagov | 0 | 0 | 96,146 | 0 | 16,448 | 0 | $1,658,843$ |
| usacap | 0 | 0 | 0 | 117,450 | 0 | $-9,600$ | 846,403 |
| usarow | 0 | 41,922 | 0 | 0 | 0 | 0 | 665,115 |
| usatar | 0 | 0 | 0 | 0 | 0 | 0 | 16,448 |
| usaerr | 0 | 0 | 0 | 0 | 0 | 0 | $-9,600$ |
| usatot | 0 | $1,658,843$ | 846,403 | 665,115 | 16,448 | $-9,600$ |  |

Table 3: Macroeconomic SAM for Mexico, 1988
(billions of Mexican pesos)

|  | mexact | mexcom | mexlab | mexpro | mexent | mexhld |
| :---: | ---: | ---: | ---: | ---: | ---: | ---: |
| mexact | 0 | 390,935 | 0 | 0 | 0 | 0 |
| mexcom | 0 | 0 | 0 | 0 | 0 | 269,173 |
| mexlab | 101,640 | 0 | 0 | 0 | 0 | 0 |
| mexpro | 255,428 | 0 | 0 | 0 | 0 | 0 |
| mexent | 0 | 0 | 0 | 238,872 | 0 | 0 |
| mexhld | 0 | 0 | 92,359 | 0 | 183,417 | 0 |
| mexvat | 13,574 | 0 | 0 | 0 | 0 | 0 |
| mexgov | 20,293 | 0 | 9,281 | 0 | 8,801 | 8,995 |
| mexcap | 0 | 0 | 0 | 0 | 46,654 | 29,811 |
| mexrow | 0 | 56,639 | 0 | 21,887 | 0 | 0 |
| mextar | 0 | 1,857 | 0 | 0 | 0 | 0 |
| mexerr | 0 | 0 | 0 | 0 | 0 | 0 |
| mextot | 390,935 | 449,430 | 101,640 | 260,760 | 238,872 | 307,978 |


|  | mexvat | mexgov | mexcap | mexrow | mextar | mexerr | mextot |
| :---: | ---: | ---: | ---: | ---: | ---: | ---: | ---: |
| mexact | 0 | 0 | 0 | 0 | 0 | 0 | 390,935 |
| mexcom | 0 | 32,961 | 81,642 | 65,655 | 0 | 0 | 449,430 |
| mexlab | 0 | 0 | 0 | 0 | 0 | 0 | 101,640 |
| mexpro | 0 | 0 | 0 | 5,332 | 0 | 0 | 260,760 |
| mexent | 0 | 0 | 0 | 0 | 0 | 0 | 238,872 |
| mexhld | 0 | 31,250 | 0 | 952 | 0 | 0 | 307,978 |
| mexvat | 0 | 0 | 0 | 0 | 0 | 0 | 13,574 |
| mexgov | 13,574 | 0 | 0 | 1,411 | 1,857 | 0 | 64,211 |
| mexcap | 0 | 0 | 0 | 5,177 | 0 | 0 | 81,642 |
| mexrow | 0 | 0 | 0 | 0 | 0 | 0 | 78,526 |
| mextar | 0 | 0 | 0 | 0 | 0 | 0 | 1,857 |
| mexerr | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| mextot | 13,574 | 64,211 | 81,642 | 78,526 | 1,857 | 0 |  |

Table 4: North American Macroeconomic SAM, 1988
(mullions of $U . S$ dollars)

|  | canact | cancom | canlab | canpro | canent | cantid | canval | cangov | cancap | cantar | canerr |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| canact | 0 | 486859 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| cancom | 0 | 0 | 0 | 0 | 0 | 285060 | 0 | 92110 | 108959 | 0 | 802 |
| carlab | 267124 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| canpro | 171200 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| canent | 0 | 0 | 0 | 155849 | 0 | 4941 | 0 | 43323 | 0 | 0 | 0 |
| canhld | 0 | 0 | 244200 | 0 | 96816 | 0 | 0 | 58209 | 0 | 0 | 0 |
| canvat | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| cangov | 49337 | 0 | 22924 | 0 | 47668 | 67822 | 0 | 0 | 2845 | 3675 | 0 |
| cancap | 0 | 0 | 0 | 0 | 59628 | 41437 | 0 | 0 | 0 | 0 | . 802 |
| cantar | 0 | 3675 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| canery | -802 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 802 | 0 | 0 |
| usasct | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| usacom | 0 | 69936 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| uecalab | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| urapro | 0 | 0 | 0 | 7247 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| uasent | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| ueshild | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| uravat | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| unagor | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| uracap | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| uratar | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| ursert | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| mexact | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| meccom | 0 | 1080 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| mexiab | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| mexpro | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| mexent | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| mexhld | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| merval | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| mexgov | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| mexcap | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| mextar | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| nexert | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| row | 0 | 54431 | 0 | 17307 | 0 | 650 | 0 | 1887 | 0 | 0 | 0 |
| total | 486859 | 615880 | 267124 | 180402 | 204112 | 399910 | 0 | 185629 | 112605 | 3675 | -1 |

Table 4, Cout.: North American Macroeconounic SAM, 1988
(milions of US doflars)

|  | usasct | usteom | usalat | usapro | ussent | uxahid | usavat | usagov | usacap | usatar | usaer |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| canact | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| cancom | 0 | 99293 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| candab | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| canpro | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| canert | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| canhld | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| canvas | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| cangov | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| cancap | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2717 | 0 | 0 |
| cantar | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| canerr | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| manct | 0 | 4830868 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| usacom | 0 | 0 | 0 | 0 | 0 | 3235095 | 0 | 968946 | 750257 | 0 | 0 |
| unatab | 2907647 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| uespro | 1555756 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| unent | 0 | 0 | 0 | 1589072 | 0 | 06146 | 0 | 02292 | 0 | 0 | 0 |
| u*abld | 0 | 0 | 2463048 | 0 | 1045732 | 0 | 0 | 555683 | 0 | 0 | 0 |
| ueavat | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| usagov | 377065 | 0 | 444598 | 0 | 137936 | 586649 | 0 | 0 | 96146 | 16448 | 0 |
| usacap | 0 | 0 | 0 | 0 | 593842 | 144711 | 0 | 0 | 0 | 0 | .9600 |
| usatar | 0 | 16448 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| unaers | .9600 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| mexact | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| meccom | 0 | 23545 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| mexiab | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| mexpro | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| merens | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| mexhld | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| mexval | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| mexgoy | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| mexcap | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| mextar | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| mexerr | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| row | 0 | 435062 | 0 | 83431 | 0 | 1882 | 0 | 41922 | 0 | 0 | 0 |
| tota | 4830868 | 5385216 | 2907647 | 1672503 | 1777510 | 4064483 | 0 | 1858843 | 849120 | 16448 | . 9600 |

Table 4, Cont.: North Anerican Macroeconomic SAM, 1988
(millions of US dollars)

|  | merac: | mexcom | mexas | mexpro | mexent | mexhld | mex vat | mexgov | mexcap | mextar | mexers | row | total |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| canact | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 486859 |
| cancom | 0 | 398 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 49359 | 615980 |
| candab | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 287124 |
| campro | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 9202 | 180402 |
| canent | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 204112 |
| cantad | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 685 | 399810 |
| canvat | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| cangor | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1358 | 195629 |
| cancap | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 9625 | 112605 |
| cantar | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3675 |
| caner | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | -1 |
| useact | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 4830868 |
| usacom | 0 | 20843 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 340339 | 5385216 |
| uasab | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2907647 |
| usapro | 0 | 0 | 0 | 1191 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 108309 | 1672503 |
| uswent | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1777510 |
| uestud | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 4064463 |
| uravas | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| usagov | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1658843 |
| usecap | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 4661 | 0 | 0 | 115506 | 849120 |
| usatar | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 16448 |
| usaerr | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | . 9600 |
| mexact | 0 | 171991 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 171991 |
| meccom | 0 | 0 | 0 | 0 | 0 | 118422 | 0 | 14501 | 35918 | 0 | 0 | 15045 | 208510 |
| medab | 44716 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 44716 |
| mexpro | 112375 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2346 | 114720 |
| mexent | 0 | 0 | 0 | 105091 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 105091 |
| mexhld | 0 | 0 | 40633 | 0 | 80694 | 0 | 0 | 13748 | 0 | 0 | 0 | 419 | 135494 |
| mervat | 5972 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 5972 |
| mexpor | 8928 | 0 | 4083 | 0 | 3872 | 3957 | 5972 | 0 | 0 | 817 | 0 | 621 | 28250 |
| mexcap | 0 | 0 | 0 | 0 | 20525 | 13115 | 0 | 0 | 0 | 0 | 0 | 6939 | 40579 |
| mextar | 0 | 817 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 817 |
| mexer r | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| row | 0 | 14662 | 0 | 8438 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 659751 |
| cotal | 171991 | 208510 | 44716 | 114720 | 105091 | 135494 | 5972 | 28250 | 40579 | 317 | 0 | 659751 |  |

1. Agriculture

Agriculture
Livestock
Forestry
Fishing \& hunting
2. Mining

Coal products
Metal ore mining
Other mining
Quarrying
Other metal ore mining

## 3. Petroleum

Petroleum extraction \& natural gas Petroleum products
Basic petrochemicals
4. Food Processing

Meat \& dairy products
Processed fruits \& vegetables
Milling of wheat \& their products
Milling of corn \& their products
Processing of coffee
Sugar \& products
Oils \& fats
Food for animals
Other processed food
5. Beverages

Alcoholic beverages
Beer, malt
Soft beverages \& syrups
6. Tobacco

Tobacco \& products
7. Textiles

Soft fiber textiles
Hard fiber textiles
Other textiles
8. Wearing Apparel

Wearing apparel
Hosiery
Knitted wear
9. Leather

Leather \& products
10. Paper

Pulp
Paper products
Printing \& publishing
11. Chemicals

Basic chemicals
Fertilizers
Synthetic fibers
Drugs \& medicine
Soaps \& detergents
Other chemical industries
12. Rubber

Rubber products
Plastic products
13. Non-Metallic Mineral Products

Glass products
Cement
Other non-metallic mineral products
14. Iron \& Steel

Steel mills
15. Non-Ferrous Metals

Non-ferrous basic industries
16. Wood \& Metal Products

Manufacturing wood
Other wood industries
Furniture
Metallic structures
Metal forgings
Other metallic products

Table 5, Cont'd.: Sectoring Scheme for Detailed North American SAM
17. Non-Electrical Machinery

Machinery \& non-electrical equipment
18. Electrical Machinery

Electrical machinery
Electrical appliances
Electronic equipment
Other electrical products
19. Transport Equipment

Motor vehicles
Motor parts
Missiles \& tanks
Other transport equipment
20. Other Manufactures

Other manufacturing industries

## 21. Construction

Construction
22. Electricity

Electricity, gas \& water
Sanitary services, irrigation
23. Commerce, Restaurants \& Hotels

Commerce (wholesale \& retail trade)
Restaurants \& hotels
24. Transport \& Communication

Transport
Communications
25. Financial and Insurance Services

Financial services
Dwellings, real estate
26. Other Services

Professional services
Educational services
Medical services
Recreational \& cultural services
Other services

Table 6: North Anerican SAM, 1988
(milluan of $U S$ dotiant

|  | casprimy | canmaut | cancomal | caseerve | caviab | caupro | canert | candid | cantareat | =atremex | castarrow | canerr |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| casprimy | 17052 | 23768 | 5479 | 5716 | 0 | 0 | 0 | 10641 | 0 | 0 | 0 | 18 |
| casmanut | sots | 9545s | 20663 | 25924 | 0 | 0 | 0 | 132176 | 0 | 0 | 0 | 218 |
| canconst | 954 | 03 | 125 | 6163 | 0 | 0 | 0 | 22702 | 0 | 0 | 0 | 136 |
| caneorve | 13571 | 44465 | 16103 | 95092 | 0 | 0 | 0 | 280600 | 0 | 0 | 0 | 430 |
| canab | 14021 | 71421 | 29504 | 153179 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| campro | 31279 | 32730 | 8419 | 108775 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| cament | 0 | 0 | 0 | 0 | 0 | 155049 | 0 | 48285 | 0 | 0 | 0 | 0 |
| ceadid | 533 | 6244 | 10501 | 32059 | 267124 | 0 | 204112 | 170313 | 2049 | 32 | 1595 | $-802$ |
| cantarseas | 22 | 2027 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| cantarmex | 0 | 32 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| camtarrow | ${ }^{17}$ | 1574 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| casers | -42 | - 214 | 49 | -457 | 0 | 0 | 0 | 802 | 0 | 0 | 0 | 0 |
| easpringy | 4823 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| nemmesf | 0 | 65113 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| eneconelt | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Taseric | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| casab | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| nespro | 0 | 0 | 0 | 0 | 0 | 7247 | 0 | c | 0 | 0 | 0 | 0 |
| uesent | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| enedit | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| nentarcan | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| ceatarmay | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| neatarrow | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| caserr | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| mexprimy | 229 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| mermanet | 0 | 25, | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| mexicomat | 0 | 0 | 0 | 0 | 0 | 0 | 0 | D | 0 | 0 | 0 | 0 |
| mescerve | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| mpalab | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| meripro | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| mexert | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| merval | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| mexdid | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| merterces | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| trextaras | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| mertariow | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| row | 407\% | 29231 | 0 | 21120 | 0 | 17307 | 0 | 2637 | 0 | 0 | 0 | 0 |

Table 6, Cont.: North American SAM, 1988
(milliona of U.S doliare)

|  | maeprimy | casmenef | neaconat | waserve | nealab | uespro | wasent | masdid | mentarcas | neatanmer | asatartom | uncerr |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| cenprimy | 9724 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| caemen uf | 0 | 69569 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| canconat | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| cancerve | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| canlab | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| cenpro | 0 | $\checkmark$ | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| cesent | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| casdid | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2717 | 0 | 0 | 0 | 0 |
| castareas | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| canter mel | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| castarrow | 0 | - | 0 | 0 | 0 | 0 | 0 | 0 | , | 0 | 0 | 0 |
| canerr | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| useprimy | 12144 | 146857 | 11691 | 102336 | 0 | 0 | 0 | 71044 | 0 | 0 | 0 | 0 |
| camerel | 37345 | 238023 | 202067 | 245704 | 0 | 0 | 0 | 1000381 | 0 | 0 | 0 | 0 |
| -20003: | 14464 | 14521 | 625 | 60070 | 0 | 0 | 0 | 491730 | 0 | 0 | 0 | 0 |
| -3aseric | 43560 | 437570 | 151223 | 1120521 | 0 | 0 | 0 | 3311163 | 0 | 0 | 0 | 0 |
| calab | 62393 | 65632 | 197013 | 2011619 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| esppro | 139418 | 196992 | 31882 | 1197647 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| necest | 0 | 0 | 0 | 0 | 0 | 1589072 | 0 | 186430 | 0 | 0 | 0 | 0 |
| coedrd | 2847 | 37024 | 7014 | 304547 | 2907647 | 0 | 1777510 | 1363198 | 723 | 643 | 15043 | -2600 |
| easharcan | so | 673 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| coutarmer | 4 | 361 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| asstarrom | 356 | 14725 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| nemer | -447 | -1927 | -521 | -6068 | 0 | - | 0 | 0 | 0 | 0 | 0 | 0 |
| mexprimy | 5460 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| mexmenet | 0 | 18085 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| mexcoant | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| mosenearve | 0 | D | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| mezlab | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| meripro | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| merent | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| merval | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| menedid | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| mextarcan | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| menertares | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| merimertow | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| row | 38552 | 307656 | 0 | cess2 | 0 | 83431 | 0 | 43784 | 0 | 0 | 0 | 0 |

Table 6, Cont.: North American SAM, 1988
(milhoar if US dollars)

|  | meriprimy | mexmener | mericonat | mencerve | mexilab | mexpro | mereat | mervat | mexdtd | mertarcan | meritaram | mextastom | row |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| camprimy | 74 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 8939 |
| camment | 0 | 320 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 23819 |
| canconal | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| camerve | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 18501 |
| caslab | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | $\bigcirc$ | 0 | 0 | 0 |
| campro | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 9202 |
| casart | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| candsd | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 11680 |
| cartarme | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| cantarmen | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| casterrow | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| casers | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| usaprimy | 2090 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 30538 |
| cuameref | 0 | 10344 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 188013 |
| -aconer | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 160 |
| ceserve | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 120828 |
| crabob | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | $0 \cdot$ | 0 | 0 |
| ueapro | 0 | 0 | 0 | 0 | 0 | 1191 | 0 | 0 | 0 | 0 | 0 | 0 | 108309 |
| nesent | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| ceadrd | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 4681 | 0 | 0 | 0 | 113506 |
| neatarcan | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| mentarmex | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| catar row | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| cenert | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| mexprimy | 10313 | 13006 | 781 | 630 | 0 | 0 | 0 | 0 | 11975 | 0 | 0 | 0 | 11640 |
| coexmenal | 6071 | 25057 | 7353 | 5172 | 0 | 0 | 0 | 0 | 60067 | 0 | 0 | 0 | 3403 |
| mexconat | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 18804 | 0 | 0 | 0 | 0 |
| meneerve | 3820 | 14046 | 4281 | 13072 | 0 | 0 | 0 | 0 | 77903 | 0 | 0 | 0 | 0 |
| maxlab | 3840 | DOS 7 | 4160 | 27840 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| mexpro | 16200 | 29035 | 2282 | 64173 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2346 |
| moxent | 0 | 0 | 0 | $\checkmark$ | 0 | 105091 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| mexemet | 1293 | 1364 | 19 | 3302 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| mexdid | 1834 | 20.50 | 29 | 4836 | 44716 | 0 | 105091 | 3972 | 30021 | - | 472 | 336 | 7974 |
| mertarcas | 0 | 9 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| mertartas | 30 | 442 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| mentar row | - | 326 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1ow | 1330 | 12823 | 0 | 0 | 0 | 4438 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

Table 7: Narth Anerican Expenditure Shares, 1988

|  | cangralt | croviming | capetral | anboodproc | crbeveras | amobecoo | caterile | caspparal | coleather | cupaper | asherrical | arubber | cmoanotini |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| capricut | 18.5 | 0.0 | 0.0 | 37.7 | 0.5 | 14.0 | 0.7 | 1.6 | 0.1 | 3.3 | 0.1 | 0.6 | 0.0 |
| caminiog | 0.2 | 0.2 | 4.0 | 0.1 | 0.0 | 0.0 | 0.1 | 0.0 | 0.0 | 0.1 | 0.6 | 0.1 | 6.6 |
| copetral | 16 | 0.1 | 25.8 | 0.5 | 0.6 | 0.2 | 0.6 | 0.2 | 0.4 | 1.0 | 3.3 | 0.3 | 1.6 |
| cutoodprox | 6.0 | 0.0 | 0.0 | 15.5 | 4.7 | 0.3 | 0.1 | 0.1 | 3.3 | 0.1 | 0.4 | 0.1 | 0.0 |
| abrueag | 0.0 | 0.0 | 0.0 | 0.1 | 6.4 | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.1 | 0.0 | 0.0 |
| clabecos | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 11.1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| caterile | 0.2 | 0.0 | 0.0 | 0.0 | 0.1 | 0.9 | 16.2 | 2.3 | 0.9 | 0.2 | 0.0 | 0.9 | 0.1 |
| capperel | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.9 | 4.0 | 0.4 | 0.0 | 0.0 | 0.0 | 0.0 |
| colenibe | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.6 | 7.5 | O. | 0.0 | 0.0 | 0.0 |
| coppapa | 0.0 | 0.0 | 0.0 | 2.4 | 3.7 | 8.1 | 1.0 | 0.6 | 1.0 | 15.9 | 0.6 | 1.2 | 1.2 |
| cocherical | 4.6 | 0.1 | 1s | 0.8 | 1.1 | 0.4 | 6.2 | 0.3 | 2.3 | 3.3 | 15.1 | 20.0 | 1.7 |
| corabem | 0.1 | 0.0 | 0.1 | 1.2 | 1.1 | 0.8 | 0.6 | 0.5 | 3.4 | 0.4 | 0.6 | 2.4 | 0.8 |
| camometue | 0.1 | 0.0 | 0.0 | 0.3 | 3.4 | 0.0 | 0.0 | 0.0 | 0.0 | 0.2 | 0.2 | 0.2 | 7.0 |
| arturom | 0.0 | 0.1 | 0.7 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.1 | 0.1 | 0.3 |
| canomerst | 0.3 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.1 | 0.0 | 0.0 | 0.3 | 0.5 | 0.2 | 0.5 |
| amoodmell | 0.5 | 0.0 | 0.2 | 1.0 | 6.7 | 0.5 | 0.1 | 0.0 | 0.4 | 3.3 | 0.3 | 0.9 | 0.9 |
| conedorac: | 0.5 | 0.1 | 0.4 | 0.0 | 0.0 | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| apecomed | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.1 |
| caxmectip | 0.2 | 0.0 | 0.0 | 0.1 | 0.0 | 0.1 | 0.0 | 0.1 | 0.1 | 0.0 | 0.0 | 0.1 | 0.1 |
| caothemend | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.2 | 0.9 | 0.6 | 0.2 | 0.0 | 6.1 | 0.1 |
| cmocestra | 1.5 | 0.0 | 1.4 | 0.2 | 0.2 | 0.4 | 0.2 | 0.1 | 0.1 | 0.3 | 0.3 | 0.2 | 0.2 |
| caelectric | 1.3 | 2.2 | 1.7 | 0.9 | 1.0 | 0.6 | 1.2 | 0.5 | 0.5 | 3.4 | 1.6 | 1.1 | 2.3 |
| ascommeror | 3.4 | 0.2 | 1.3 | 3.0 | 1.4 | 1.5 | 2.0 | 2.5 | 2.7 | 2.1 | 1.3 | 1.7 | 2.1 |
| cutracomite | 36 | 0.1 | 20 | 3.0 | 1.5 | 1.5 | 1.2 | 0.9 | 1.0 | 2.9 | 1.7 | 1.1 | 2.8 |
| afrimu | 19 | 0.2 | 4.9 | 1.5 | 2.2 | 3.3 | 1.4 | 31 | 22 | 1.7 | 1.7 | 1.4 | 1.6 |
| costhervi | 6.6 | 0.3 | 11. | 4.3 | 9.5 | 10.3 | 3.3 | 3.9 | 2.5 | 6.3 | 4.3 | 4.2 | 4.7 |
| canle | 1s. | 34.4 | 10.0 | 17.2 | 20.9 | 16.4 | 21.7 | 24.8 | 16.8 | 27.7 | 17.7 | 27.1 | 26.2 |
| ceapro | 29.1 | 38.1 | 18.6 | 9.9 | 18.8 | 25.5 | 0.0 | 5.7 | 2.6 | 16.1 | 16.7 | 7.0 | 16.8 |
| ceedid | -0.6 | 4.2 | 6.2 | 0.8 | 4.1 | 20 | 1.7 | 0.6 | 1.0 | 2.8 | 17 | 2.2 | 1.7 |
| cemer | 0.1 | 0.0 | 0.0 | 0.4 | 3.0 | 0.2 | 1.4 | 4.0 | 5.9 | 0.3 | 1.2 | 1.7 | 0.9 |
| mexam | 4.0 | 18.6 | 2.5 | 4.4 | 1.2 | 0.7 | 14.1 | 1.5 | 10.2 | 6.4 | 17.4 | 18.8 | 10.6 |
| umicoma | 0.1 | 0.3 | 0.2 | 0.1 | 0.2 | 0.0 | 0.4 | 0.1 | 0.1 | 0.0 | 0.1 | 0.0 | 0.2 |
| row | 1.4 | 3.5 | 0.4 | 4.5 | 7.2 | 0.9 | 14.3 | 20.8 | 33. | 1.4 | 2.4 | 5.4 | 7.0 |
|  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| capaicali | 0.0 | 0.0 | 8.4 | 0.0 | 0.0 | 0.0 | 0.0 | 0.2 | D. | 0.5 | 0.1 | 0.0 | 0.1 |
| camining | 48 | 18.4 | 1.8 | 0.3 | 0.0 | 0.0 | 2.3 | 4.6 | 4.3 | 0.0 | 0.0 | 0.0 | 0.0 |
| capetrol | 1.2 | as | 0.5 | 0.4 | 0.2 | 0.3 | 1.2 | 1.2 | 1.4 | 0.7 | 2.4 | 0.4 | 0.5 |
| cmaodproc | 0.1 | 0.0 | 0.1 | 0.1 | 0.0 | 0.0 | 0.1 | 0.1 | 0.0 | 2.4 | 0.0 | 0.0 | 0.4 |
| abeveras: | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.1 | 0.0 | 0.0 | 0.1 |
| clubecce | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| cramile | 0.0 | 0.0 | 0.4 | 0.1 | 0.0 | 0.4 | 0.8 | 0.7 | 0.0 | 0.1 | 0.0 | 0.0 | 0.1 |
| caepperel | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.1 | 0.0 | 0.0 | 0.1 |
| coleatur | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.2 | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| соререт | 0.0 | 0.0 | 0.6 | 0.2 | 0.5 | 0.2 | 2.0 | 0.4 | 0.0 | 0.6 | 0.1 | 0.1 | 4.5 |
| ancreical | 0.8 | 0.6 | 1.8 | 0.3 | 0. | 1.1 | 2.4 | 1.3 | 0.0 | 0.1 | 0.3 | 0.0 | 1.1 |
| cmuber | 0.0 | 0.0 | 0.7 | 0.8 | 0.6 | 1.1 | 2.6 | 1.5 | 0.0 | 0.3 | 0.2 | no | 0.6 |
| amoneme | 1.7 | 0.1 | 0.4 | 0.2 | 0.3 | 0.7 | 0.8 | 4.4 | 0.0 | 0.0 | 0.0 | 0.0 | 0.1 |
| cateriom | 11.4 | a. 3 | 5.9 | 8.7 | 1.2 | 3.2 | 0.7 | 0.9 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| creoderst | 36 | 10.1 | 3.2 | 1. | - 2.1 | 2.0 | 2.5 | 0.2 | 0.4 | 0.0 | 0.9 | 0.0 | 0.1 |
| cawoodmel | 1.4 | 0.4 | 4.1 | 4.7 | 1.5 | 2.9 | 1.4 | 9.9 | 0.0 | 0.2 | 0.1 | 0.0 | 0.6 |
| cancolemac | 0.2 | 0.0 | 0.2 | 7.6 | 0.7 | 0.8 | 0.1 | 0.6 | 0.1 | 0.0 | 0.0 | 0.0 | 0.7 |
| coelocrund | 0.4 | 0.5 | 0.2 | 1.1 | 14.1 | 1.6 | 1.9 | 1.6 | 0.1 | 0.0 | 0.4 | 0.0 | 0.9 |
| conrmeapt | 0.2 | 0.1 | 0.3 | 1.1 | 0.2 | 21.3 | 0.2 | 0.2 | 0.0 | 0.0 | 0.9 | 0.0 | 0.4 |
| crothenered | 0.1 | 0.0 | 0.3 | 0.3 | 0.4 | 0.4 | 5.2 | 0.9 | 0.0 | 0.0 | 0.0 | 0.0 | 0.4 |
| crocemitet | 0.5 | 0.2 | 0.2 | 0.2 | 0.1 | 0.2 | 0.2 | 0.1 | 1.9 | 0.4 | 1.9 | 1.7 | 1.8 |
| comearic | 3.1 | 1.1 | 1.2 | 0.6 | 0.5 | 0.6 | 0.6 | 0.1 | 0.5 | 1.5 | 0.1 | 1.6 | 0.3 |
| cecomersice | 2.8 | 0.8 | 3.3 | 2.8 | 1.9 | 23 | 2.4 | 4.7 | 0.4 | 1.2 | 2.2 | 0.4 | 4.9 |
|  | 3.0 | 1.2 | 2.2 | 1.3 | 2.3 | 1.7 | 1.4 | 3.1 | 0.6 | 2.0 | 25.4 | 1.2 | 4.8 |
| cafricom | 0.0 | 0.3 | 18 | 1.6 | 2.1 | 0.8 | 26 | 2.3 | 1.2 | 5.9 | 26 | 2.0 | 31 |
| contmarn | 6.0 | 1.5 | 4.4 | 3.9 | 4.3 | 5.2 | 5.3 | 7.4 | 10 | 7.1 | 50 | 7.1 | 7.4 |
| casleb | 25.6 | 21.4 | 20.7 | 10.6 | 19.7 | 11.6 | 16.0 | 32.5 | 23.7 | 54.2 | 33.1 | 35.4 | 21.6 |
| canpro | as | 180 | 7.7 | 3.8 | 73 | 3.7 | 4.5 | 9.3 | 54.2 | 15.9 | 17.9 | 21.1 | 30.3 |
| candid | 2.5 | 1.1 | 2.0 | 0.7 | 1.4 | 0.8 | 1.3 | 11.5 | 3.0 | 5.7 | 1.3 | 14.0 | 7.4 |
| camer | 0.7 | 0.4 | 0. | 1.0 | 1.5 | 0.4 | 1.4 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| mecosos | 7.3 | 18.2 | 9.8 | 36. | 230 | 28.8 | 17.1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| mexicom | 0.1 | 0.1 | 0.1 | 0.8 | 0.7 | 0.2 | 0.3 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| rom | 4. | 4.4 | 3.9 | 13.0 | 11.7 | 63 | 22.5 | 0.0 | 0.6 | 1.0 | 4.1 | 0.9 | 6.0 |

Table 7, Cont: North American Expenditure Slares, 1988

|  | mangicul | mainies | mepetrol | Eloodproce | unbereay | - | uneriden | mappand | maleatmer | mpaper | ancheracal | norubber | croametre |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| cancom | 0.4 | 0.8 | 3.5 | 0.4 | 0. ${ }^{\text {c }}$ | 0.1 | 0.5 | 0.4 | 0.1 | 3.8 | 0.2 | 0.8 | 0.4 |
| magrical | 19.4 | 0.0 | 0.0 | 23.6 | 3.4 | 0.7 | 1.6 | 0.6 | 0.0 | 0.1 | 0.6 | 0.1 | 0.0 |
| maimat | 0.0 | so | 0.0 | 0.0 | 0.0 | 00 | 0.1 | 0.0 | 0.0 | د0 | 1.0 | 0.1 | 2.2 |
| -patrol | 1.5 | 0.4 | 30.0 | 0.3 | 0.3 | 0.3 | 0.5 | 0.1 | 0.1 | 1.1 | 6.9 | 3.4 | 3.4 |
| -roodpror | 0.6 | 0.0 | 0.0 | 12. | 7.1 | 0.0 | 0.0 | 0.0 | 34 | 0.2 | 1.0 | 0.1 | 0.0 |
| mbewtag | 0.0 | 0.0 | 0.0 | 0.3 | 12. | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| urobemas | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 35.3 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| crextion | 0.2 | 0.1 | 0.0 | 0.0 | 0.0 | 0.1 | 36.2 | 19.1 | 1.3 | 1.2 | 0.1 | 2.3 | 0.5 |
| -appere | 0.0 | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.4 | 14.1 | 0.1 | 0.0 | 0.0 | 0.1 | 0.1 |
| meatime | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.4 | $0 \cdot 8$ | 13.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| -paper | 0.2 | 0.1 | 0.1 | 4.1 | 4.1 | 1.4 | 1.3 | O. ${ }^{\text {a }}$ | 0.3 | 23.5 | 2.3 | 2.8 | 2. |
| cectruical | 8.0 | 1.1 | 0.9 | 1.2 | 1.0 | 0.7 | 5.0 | 0.2 | 0.6 | 2.5 | 16.4 | 9.0 | 2.2 |
| -mrubiow | 0.3 | 0.4 | 0.0 | 1.1 | 0.7 | 1.2 | 2.5 | 0.3 | 0.4 | 2.5 | 2.7 | 14.4 | 1.1 |
| - moumer | 0.1 | 0.4 | 0.0 | 0.8 | 7.0 | 0.0 | 0.1 | 0.0 | 0.0 | 0.1 | 0.6 | 0.7 | 4.1 |
| merrome | 0.0 | 0.2 | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 | 00 | 0.0 | 0.1 | 0.2 | 0.8 | 0.3 |
| cmontrot | 0.0 | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.2 | 0.4 | 0.3 | 0.5 |
| -moodurell | 0.2 | 0.9 | 0.2 | 1.4 | 12.3 | 0.3 | 0.1 | 0.0 | 0.4 | 3.6 | 1.7 | 1.2 | 1.9 |
| mandemax | 0.9 | 31. | 0.3 | 0.2 | 0.6 | 0.3 | 0.9 | 0.3 | 0.1 | 0.5 | 1.4 | 1.3 | 1.2 |
| -decrasel | 0.3 | 0.3 | 0.1 | 0.0 | 0.0 | 0.1 | 0.0 | 0.1 | 0.0 | 0.1 | 0.1 | 0.2 | 0.2 |
| eirmeape | 0.3 | 0.1 | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.1 | 0.1 |
| cothaner | 0.0 | 0.1 | 0.0 | 0.0 | 0.1 | 0.0 | 0.1 | 1.2 | 0.3 | 0.7 | 0.3 | 0.3 | 0.4 |
| moserat | 0.6 | 0.3 | 5.0 | 0.4 | 0.7 | 0.2 | 0.3 | 0.1 | 0.1 | 0.6 | 0.6 | 0.6 | 1.1 |
| -dectric | 0.9 | 1.4 | 1.0 | 1.5 | 1.6 | 0.2 | 1.7 | 0.4 | 0.2 | 28 | 4.1 | 3.1 | 5.6 |
| -momerse | 38 | 1.9 | 0.6 | 6.4 | 7.0 | 1.3 | 14 | 2.5 | 0.9 | 5.7 | 4.4 | 3.4 | 4.0 |
| -trecome | 1.2 | 0.8 | 1.9 | 2.7 | 28 | 0.4 | 1.2 | 0.0 | 0.3 | 3.6 | 3.3 | 2. | 5.1 |
| -taime | 4.6 | 1.4 | 1.2 | 1.0 | 21 | 1.7 | 0.4 | 0.8 | 0.3 | 1.8 | 20 | 1.4 | 1.7 |
| motherw | 23 | 21 | 0.9 | 4.0 | 7.4 | 10 | 2.7 | 20 | 0.8 | 6.3 | 9.3 | 4.8 | 4.2 |
| -acab | 15.3 | 4.4 | 7.0 | 12.8 | 9.1 | 11.6 | 23.9 | 16.3 | 10.3 | 25.7 | 15.5 | 21.9 | 30.8 |
| -xpo | 7.9 | 23.5 | 20.1 | 0.7 | 4.2 | 28.1 | 4.1 | 5.2 | 7.6 | 11.2 | 14.1 | 9.1 | 10.4 |
| medd | 3.6 | 2.5 | 7.5 | 0.5 | 21 | 10.8 | 1.2 | 0.3 | 0.2 | 13 | 1.5 | 1.6 | 2.1 |
| meler | 0.1 | 0.0 | 0.1 | 0.2 | 0.3 | 0.2 | 0.7 | 4. | 4.0 | 0.0 | 0.4 | 0.3 | 0.5 |
| $\cdots \mathrm{mancam}$ | 0.8 | 0.4 | 1.7 | 0.2 | 0.5 | 0.1 | 0.2 | 0.6 | 1.1 | 0.2 | 0.5 | 0.3 | 0.0 |
| now | 2.8 | 7.1 | 122 | 3.2 | 5.4 | 1.9 | 4.0 | 2.5 | 50.6 | 2.0 | 7.4 | 7.7 | 8.9 |
|  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| cnocos | 1.7 | 3.0 | 2.1 | 1.8 | 10 | 4. | 1.7 | 00 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| mapicul | 0.0 | 0.0 | 2.6 | 0.0 | 0.0 | 0.0 | 0.1 | 0.4 | 0.0 | 0.3 | 00 | 0.6 | 0.3 |
| moining | 4.0 | 21 | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.4 | 2.5 | 0.0 | 0.0 | 0.0 | 0.0 |
| epertod | 1.2 | 0.9 | 0.4 | 0.4 | 0.2 | 0.2 | 0.4 | 1.2 | 12.2 | 0.1 | 3. | 0.3 | 0.4 |
| maodproc | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.2 | 0.0 | 0.0 | 0.1 | 0.1 | 0.0 | 2.0 |
| Imbertac | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.1 | 0.0 | 0.0 | 0.6 |
| matemos | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 00 | 0.0 | 0.0 | 0.0 | 0.0 |
| crantem | 0.0 | 0.1 | 0.4 | 0.1 | 0.0 | 1.2 | 1.5 | 0.6 | 0.0 | 0.1 | 0.1 | 0.0 | 0.1 |
| -apperes | 0.1 | 0.0 | 0.1 | 0.0 | 0.1 | 0.0 | 0.1 | 0.0 | 0.0 | 0.1 | 0.1 | 0.0 | 0.2 |
| colactive | 0.0 | 0.0 | 0.1 | 0.0 | 0.0 | 0.0 | 0.2 | 0.0 | 0.0 | 0.0 | 00 | 0.0 | 0.0 |
| neperax | 0.2 | 0.3 | 1.0 | 0.8 | 0.9 | 0.2 | 2.3 | 0.4 | 0.1 | 1.2 | 0.3 | 0.8 | 1.4 |
| echerrical | 2.9 | 1.5 | 1.6 | 0.4 | 0.6 | 0.4 | 1.9 | 1.3 | 0.3 | 0.1 | 0.1 | 0.1 | 1.2 |
| mrubicm | 0.2 | 1.4 | 1.6 | 1.3 | 2.6 | 2.5 | 3.5 | 1.2 | 0.0 | 0.3 | 0.3 | 0.1 | 0.3 |
| mmonative | 0.9 | 0.3 | 0.5 | 0.7 | 0.6 | 0.6 | 0.6 | 6.4 | 0.0 | 0.1 | 0.0 | 0.0 | 0.1 |
| -terrom | 14.5 | 0.4 | 7.2 | 0.0 | 1.3 | 3.0 | 0.7 | 1.3 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| - eromerre | 2.4 | 31.3 | 4.3 | 24 | 3.1 | 1.6 | 2.4 | 1.4 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| monoodmint | 1.9 | 1.3 | 14.9 | 3.4 | 3.2 | 5.6 | 27 | 14.5 | 0.2 | 0.2 | 0.2 | 0.0 | 0.5 |
| manakrax | 3.7 | 25 | 2.1 | 16.5 | 1.4 | 30 | 0.4 | 1.4 | 0. | 0.1 | 0.4 | 0.0 | 0.4 |
| melecrmat | 0.9 | 0.5 | 0.1 | 2.9 | 15.2 | 4.5 | 4.0 | 4.8 | 0.2 | 0.2 | 0.7 | 0.1 | 1.0 |
| butrsocye | 0.2 | 0.0 | 0.3 | 0.7 | 0.2 | 10.6 | 0.1 | 0.0 | 0.0 | 0.1 | 1s | 0.0 | 0.6 |
| cothurama | 0.4 | 0.1 | 0.2 | 0.3 | 0.6 | 0.6 | 5.3 | 0.5 | 0.3 | 0.3 | 0.1 | 0.2 | 1.0 |
| cromotret | 2.3 | 0.6 | 0.7 | 0.5 | 0.3 | 0.2 | 0.3 | 0.1 | 37 | 0.9 | 1.9 | 2.9 | 0.7 |
| melertic | 7.8 | 5.3 | 1.7 | 1.3 | 0.9 | 0. | 0.9 | 0.4 | 4.5 | 2.5 | 1.0 | 1.3 | 1.3 |
| ucommence | 7.7 | 6.9 | 4.9 | 5.1 | 5.1 | 3.5 | 4.2 | 12.2 | 1.2 | 1.4 | 1.7 | 0.8 | 2.7 |
| etruecoman | 4.4 | 3.4 | 2.1 | 1.8 | 1.4 | 1.1 | 1.9 | 2.3 | 1.4 | 2.7 | 0.9 | 1.2 | 2.3 |
| -inima | 1.5 | 1.4 | 1.6 | 1.6 | 20 | 0.9 | 1.6 | 1.6 | 1.1 | 5.4 | 2.4 | 15.6 | 3.3 |
| -ocimarve | 3.4 | 3.1 | 4.2 | 5.2 | 4.5 | 3.3 | 5.6 | 0.6 | 1.4 | 12.9 | 5.6 | 7.3 | 9.0 |
| ceale | 18.2 | 17.3 | 30.7 | 22.8 | 24.0 | 30.0 | 19.0 | 32. | 139 | 40. | 37.5 | 17.8 | 54.0 |
| -mepro | 1.6 | 4.3 | 6.3 | 7.4 | 6.9 | -4.2 | 12.3 | 53 | 31.4 | 15.6 | 21.9 | 41.3 | 14.8 |
| meatd | 1.3 | 1.4 | 1.3 | 0.4 | 0.7 | 1.4 | 0.6 | 1. | 4.1 | 12.9 | 4.4 | 9.1 | 1.2 |
| menem | 0.6 | 0.1 | 0.2 | 0.5 | 0.6 | 0.4 | 0.9 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| uencoms | 0.4 | 0.9 | 0.4 | 0.4 | 1.7 | 0.4 | 0.4 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| now | 12.8 | 4.4 | 6.2 | 14.5 | 19.3 | 12.4 | 23.4 | 0.0 | 14.0 | 0.0 | 6.4 | 0.0 | 0.1 |

Table 7, Cont.: North Aurrican Expenciture Slanes, 1988


Table 8: Narth American Reocipt Shares, 1988
(percementer)

|  | cangricult | camising | capetrol | crinoodproc | cabeverag | crutames | arertien | cauppered | criselber | capaper | enchemical | arrubber | anoameme |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| capricat | 10.5 | 0.4 | 3.6 | 5.1 | 0.2 | 0.1 | 0.8 | 0.0 | 0.0 | 0.0 | 0.6 | 0.3 | 0.3 |
| amining | 0.0 | 0.2 | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.1 | 0.0 | 0.0 |
| copatred | 0.0 | 4.0 | 28.4 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 21 | 0.3 | 0.1 |
| catoodiproc | 32.7 | 0.3 | 0.6 | 15.3 | 0.4 | 0.2 | 0.2 | 0.1 | 0.1 | 2.4 | 1.4 | 4.7 | 1.4 |
| catomerap | 0.1 | 0.0 | 0.1 | 0.4 | 6.3 | 0.0 | 0.1 | 0.0 | 0.0 | 0.7 | 0.3 | 0.4 | 27 |
| crobecos | 0.7 | 0.0 | 0.0 | 0.0 | 0.0 | 11.1 | 0.2 | 0.0 | 0.0 | 0.4 | 0.0 | 0.1 | 0.0 |
| ceverile | 0.2 | 0.0 | 0.1 | 0.0 | 0.0 | 0.0 | 16.2 | 0.6 | 0.0 | 0.2 | 23 | 0.5 | 0.0 |
| ceapparal | 0.8 | 0.0 | 0.1 | 0.0 | 0.0 | 0.0 | 25.7 | 4.0 | 3.1 | 0.1 | 0.1 | 0.5 | 0.0 |
| colmester | 0.0 | 0.0 | 0.0 | 0.2 | 0.0 | 0.0 | 0.3 | 0.1 | 7.4 | 0.1 | 0.3 | 0.9 | 0.0 |
| copaper | 3.9 | 0.2 | 1.2 | 0.1 | 0.1 | 0.0 | 0.8 | 0.0 | 0.3 | 15.9 | 5.5 | 1.3 | 0.9 |
| ancherical | 0.1 | 0.4 | 2.3 | 0.2 | 0.2 | 0.0 | 0.1 | 0.0 | 0.1 | 0.3 | 13.1 | 1.5 | 0.5 |
| carmber | 0.2 | 0.0 | 0.1 | 0.0 | 0.1 | 0.0 | 1.0 | 0.0 | 0.1 | 0.3 | 4.4 | 2.8 | 0.2 |
| camamere | 0.0 | 3.5 | 0.4 | 0.0 | 0.0 | 0.0 | 0.1 | 0.0 | 0.0 | 0.3 | 0.6 | 0.7 | 7.0 |
| cabreme | 0.0 | 7.1 | 0.8 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.4 | 0.1 | 2.6 |
| cmeoders | 0.0 | 12.7 | 0.2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | as | 0.0 | 0.1 |
| cmoodmal | 10.3 | 4.8 | 0.6 | 0.1 | 0.1 | 0.0 | 2.1 | 0.1 | 0.6 | 0.7 | 26 | 3.0 | 2.1 |
| conelame | 0.0 | 0.5 | 0.4 | 0.1 | 0.1 | 0.1 | 0.2 | 0.0 | 0.0 | 0.2 | as | 1.4 | 0.7 |
| celecmeat | 0.0 | 0.1 | 0.2 | 0.0 | 0.1 | 0.0 | 0.1 | 0.0 | 0.0 | 0.3 | 1.0 | 1.7 | 1.1 |
| carmeers | 0.0 | 0.1 | 0.7 | 0.1 | 0.1 | 0.1 | 4.7 | 0.1 | 6.5 | 0.4 | 4.4 | 16.3 | 7.2 |
| cmotherand | 0.0 | 2.0 | 0.5 | 0.0 | 0.0 | 0.1 | 1.4 | 0.0 | 0. | 0.7 | 1.s | 3.8 | 0.6 |
| cmonemer | 0.6 | 25.9 | 3.3 | 0.3 | 0.5 | 0.1 | 6.0 | 0.2 | 0.3 | 0.9 | 5.2 | 14.4 | 46.9 |
| coselstat | 0.0 | s.a | 0.4 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| cmevemerspe | 1.7 | 0.1 | 2.5 | 0.9 | 1.5 | 0.1 | 1.4 | 0.6 | 0.1 | 1.8 | 0.4 | 3.1 | 0.5 |
| cmarmosmen | 0.3 | 0.1 | S. 1 | 0.1 | 0.1 | 0.0 | 0.3 | 0.0 | 0.0 | 0.2 | 1.0 | 1.9 | 0.3 |
| crimimer | 0.0 | 0.1 | 1.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.3 | 0.0 | 0.0 | 0.0 |
| anotherve | 0.6 | 0.4 | 2.5 | 3.3 | 2.8 | 0.1 | 2.7 | 1.4 | 2.7 | 19.7 | 0 | 12.4 | 1.4 |
| candild | 10.1 | 4.4 | 19.6 | 59.2 | 70.5 | 0.0 | 22.6 | 87.3 | 71. | 14.9 | 24.1 | 12.4 | 0.9 |
| mecom | 2.6 | 1.4 | 28.6 | 3.4 | 68 | 1.0 | 5.4 | 3.7 | 1.0 | 20. | 21 | 10.6 | 3.5 |
| $x$ uncoim | 0.2 | a. 1 | 0.0 | 0.1 | 0.0 | 0.0 | 0.1 | 0.0 | 0.0 | 0.1 | 0.0 | 0.1 | 0.0 |
| row | 14.9 | 14.4 | 1.2 | 4.1 | 1.2 | 3.2 | 5.3 | 1.2 | 5.4 | 10.5 | 1.7 | Q. 1 | 9.3 |
|  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| conert | 0.0 | 0.8 | 0.4 | 0.5 | 0.1 | 0.1 | 0.1 | 0.5 | 2.3 | 1.0 | 1.7 | 1.6 | 1.3 |
| camist | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.2 | 0.0 | 0.0 | 0.0 | 0.0 |
| oppoted | 0.3 | 0.0 | 0.1 | 0.4 | 0.1 | 0.0 | 0.1 | 0.5 | 2. | 0.4 | 0.0 | 1.9 | 2.3 |
| ctoodprox | 0.0 | 0.1 | 1.0 | 0.0 | 0.1 | 0.0 | 0.1 | 0.1 | 1. | 2.0 | 1.7 | 0.7 | 1.0 |
| caberata | 0.0 | 0.0 | 1.1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.4 | 0.1 | 0.2 | 0.2 | 0.4 |
| cretecico | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.1 | 0.0 | 0.0 | 0.1 | 0.1 |
| apertile | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.1 | 0.0 | 0.5 | 0.1 | 0.1 | 0.2 | 0.2 |
| cespparel | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.6 | 0.0 | 0.2 | 0.2 | 0.1 | 0.4 | 0.2 |
| arectere | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.1 | 0.0 | 0.1 | 0.1 | 0 | 0.1 | 0.0 |
| capape | 0.1 | 1.2 | 3.2 | 0.0 | 0.1 | 0.0 | 0.7 | 0.1 | 6. | 0.7 | 1.6 | 0.4 | 1.6 |
| ancmial | 0.1 | 1.0 | 0.2 | 0.0 | 0.0 | 0.0 | 0.1 | 0.1 | 1.8 | 0.3 | 0.6 | as | 0.6 |
| carmber | 0.0 | 0.2 | 0.2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.1 | 0.3 | 0.2 | 0.2 |
| camonorime | 0.2 | 0.4 | 0.2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 1.0 | 0.2 | as | 0.2 | 0.2 |
| apterros | 11.4 | 4.1 | 0.5 | 0.1 | 0.3 | 0.0 | 0.1 | 0.1 | 2.1 | 0.3 | 0.6 | 0.2 | 0.5 |
| cancemer | 0.2 | 10.1 | 0.1 | 0.0 | 0.2 | 0.0 | 0.0 | 0.0 | 0.6 | 0.1 | 0.2 | 0.0 | 0.1 |
| cmoodmel | 18.5 | 11.6 | 4.1 | 0.2 | 0.3 | 0.1 | 0.9 | 0.1 | 2.4 | 1.2 | 1.3 | 0.9 | 1.1 |
| conericanac | 13.7 | 4.2 | 36 | 7.6 | 1.2 | 0.4 | 0.6 | 0.1 | 0.9 | 0.7 | 0.8 | 0.6 | 0.7 |
| condecmect | 2.5 | 8.1 | 1.0 | 0.6 | 14.1 | 0.1 | 0.4 | 0.0 | 0.7 | 0.5 | 0. | 0.7 | 0.7 |
| cintresapt | 22.4 | 10.4 | 6.5 | 2.4 | 6.1 | 21.3 | 2.5 | 0.2 | 2.7 | 1.0 | 23 | 1.0 | 2. |
| certhmear | 0.4 | 3.2 | 0.5 | 0.0 | 1.0 | 0.0 | 5.2 | 0.0 | 0.3 | 0.3 | as | 0.5 | 0.4 |
| amcoentict | 0.6 | 1.8 | 22.6 | 1.4 | 5.3 | 0.2 | 53 | 0.1 | 0.6 | 3.8 | 4.1 | 2.6 | 4.0 |
| cosectic | 0.0 | 0.7 | 0.0 | 0.0 | 0.1 | 0.0 | 0.0 | 0.4 | 0.5 | 0.1 | 0.2 | 0.3 | 0.3 |
| cicommers | 0.3 | 0.3 | 0.6 | 0.1 | 0.2 | 0.0 | 0.3 | 0.5 | 4.5 | 1.2 | 3.3 | 3.3 | 4.7 |
| citrecomm | 0.2 | 5.3 | 0.2 | 0.1 | 1.0 | 0.6 | 0.2 | 1.4 | 2.9 | 1.3 | 25.4 | 2.2 | 20 |
| catime | 0.0 | 0.0 | 0.0 | 0.0 | 0.1 | 0.0 | 0.0 | 1.5 | 6.4 | 0.3 | 1.4 | 4.0 | 3.4 |
| cmetherse | 0.3 | 1.3 | 3.5 | 4.0 | B.8 | 0.7 | 9.1 | 20 | 3.0 | 7.3 | 11.6 | 6.6 | 7.4 |
| candrd | 0.5 | 0.7 | 220 | 57.6 | 44 | 32.7 | 52.7 | 91.2 | 4. 9 | 73.3 | 29.8 | 30.9 | 81.3 |
| -nconea | 120 | 21.4 | 18.7 | 11.6 | 14.0 | 40.7 | 15.3 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| memonem | 0.3 | 0.0 | 0.0 | 0.2 | 0.1 | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 | 0 | 0.0 | 0.0 |
| row | 3.1 | 10.1 | 4.5 | 12.7 | 5.3 | 27 | 4.7 | 0.0 | 3.7 | 3.7 | 10.5 | 1.3 | 2.1 |

Table \&, Cout: North Ansrican Reocipt Shares, 1988
(pecterisoo)

|  | magricun | पraining | uspersol | enfoodprox | untiverag | netoterso | nutexilea | usppearal | ploatber | mpaper | mebeurical | erubber | atm |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| cascras | 0.6 | 9.1 | 0.3 | 0.5 | 0.1 | 0.0 | 1.3 | 0.2 | 1.4 | 1.1 | 14 | 1.3 | 1.2 |
| mapricak | 19.8 | 0.3 | 1.3 | 4.5 | 0.1 | 0.0 | 0.5 | 0.0 | 0.2 | 0.2 | 44 | 0.5 | 0.2 |
| -maxiey | 0.0 | 30 | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.1 | 0.1 | 6.2 |
| mparol | 0.0 | 0.1 | 30.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.1 | 1.0 | 0.1 | 0.1 |
| croodprox | 42 | 0.3 | 0.4 | 12.9 | 1.4 | 0.0 | 0.1 | 0.1 | 0.0 | 5.6 | 1.7 | 25 | 2.1 |
| -beverap | 0.9 | a. | 0.1 | 1.3 | 12.4 | 0.0 | 0.0 | 0.0 | 0.0 | 10 | 0.1 | 0.3 | 5.4 |
| cutabeos | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 | 36.5 | 0.0 | 0.0 | 0.0 | 0.2 | 0.1 | 0.3 | 0.0 |
| ceveriter | 0.7 | 0.3 | 0.2 | 0.0 | 0.0 | 0.0 | 5.2 | 0.4 | 2.0 | 08 | 3.1 | 1.7 | 0.1 |
| empensal | 0.3 | 0.0 | 0.1 | 0.0 | 0.0 | 0.0 | 12.2 | 18.1 | 3.4 | 0.2 | 0.1 | 0.2 | 0.0 |
| meation | 0.0 | 0.0 | 0.0 | 0.2 | 0.0 | 0.0 | 0.3 | 0.0 | 15.0 | 0.0 | 0.1 | 0.1 | 0.0 |
| -mpapm | 0.1 | 1.5 | 1.0 | 0.2 | 0.1 | 0.0 | 2.4 | 0.1 | 0.2 | 23.5 | 2.5 | 4.1 | 0.3 |
| necharical | 0.7 | 1.2 | 4.1 | 1.1 | 0.2 | 0.0 | 0.3 | 0.0 | 0.1 | 2.3 | 16.4 | 4.3 | 1.7 |
| mraber | 0.0 | 0.7 | 1.0 | 0.1 | 0.0 | 0.0 | 3.3 | 0.1 | 0.2 | 1.7 | 6.1 | 14.4 | 1.3 |
| creomarime | 0.0 | s. 6 | 1.0 | 0.0 | 0.0 | 0.0 | 0.4 | 0.0 | 0.1 | 0.9 | 0.7 | a. 6 | 4.1 |
| mietrom | 0.0 | 15.0 | 0.4 | 0.0 | 0.0 | 0.0 | 0.0 | 0.1 | 0.1 | 0.1 | 1.2 | 0.2 | 1.1 |
| -moters | 0.0 | 3.7 | 0.3 | 0.0 | 0.0 | 0.0 | 0.1 | 0.0 | 0.0 | 0.1 | 0.8 | 1.1 | 0.3 |
| -modmend | 3.8 | 0.7 | 0.5 | 0.0 | 0.1 | 0.0 | 2.8 | 0.3 | 1.1 | 1.3 | 2.1 | 3.5 | 2.2 |
| cmencmer | 0.0 | 0.1 | 0.3 | 0.0 | 0.1 | 0.0 | 0.3 | 0.1 | 0.0 | 0.5 | 0.3 | 1. ${ }^{\text {a }}$ | 14 |
| medecanct | 0.0 | 0.2 | 0.3 | 0.0 | 0.1 | 0.0 | 0.3 | 0.3 | 0.1 | 1.5 | 1.0 | 7.1 | 3.2 |
| mernexge | 0.0 | 0.2 | 0.3 | 0.0 | 0.0 | 0.0 | 4.1 | 0.1 | 0.1 | 0.4 | 0.7 | 7.6 | 3.6 |
| nortmend | 0.0 | 0.2 | 0.2 | 0.1 | a. 0 | 0.0 | 20 | 0.2 | 1.2 | 1.3 | 1.1 | 3.2 | 1.0 |
| momatat | 2.1 | 7.8 | 28 | 0.0 | 0.1 | 0.0 | 3. | 0.2 | 0.1 | 1.0 | 3.5 | 8.1 | 51.9 |
| - mectic | 0.0 | 2.4 | 14.3 | 0.0 | 0.0 | 0.0 | 0.0 | 0.1 | 0.0 | 0.2 | 0.4 | 0.1 | 0.1 |
| 0 | 1.4 | 0.0 | 3.3 | 0.3 | 1.7 | 0.0 | 1.4 | 1.0 | 1.9 | 5.3 | 0.8 | 21 | 1.0 |
| mircecome | 0.0 | 0.0 | 2.7 | 0.1 | 0.3 | 0.0 | 0.3 | 0.4 | 0.1 | 0.5 | 0.2 | 1.0 | 0.3 |
| ciskener | 3.6 | 0.1 | a.s | 0.0 | 0.1 | 0.0 | 0.5 | 0.0 | 0.4 | 4.2 | 0.5 | 0.8 | 0.2 |
| -otherw | 30 | 0.1 | 3.5 | 13.6 | 23.3 | 0.0 | 2.5 | 4. | 3.1 | 173 | 11.7 | 5.5 | 3.9 |
| meatd | 120 | 4.2 | 17.) | 58.3 | 0.3 | 556 | 15.9 | n. | 67.7 | 24.7 | 25.2 | 14.1 | 6.4 |
| masomem | 0.7 | 0.4 | 0.2 | a. 3 | 0.0 | 0.0 | 0.4 | 0.4 | 1.1 | 0.4 | 0.8 | a. | 0.2 |
| tow | 2. | 4.4 | 3.7 | 3.3 | 0.8 | . 3 | 2.0 | 0.8 | 0.5 | 3.4 | 12.4 | 11.4 | 1.9 |
|  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| catcom | 1.0 | 22 | 1.3 | 5.7 | 1.7 | 6.3 | 1.9 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 00 |
| mapicat | 0. | 0.0 | 0.2 | 0.9 | 0.2 | 0.2 | 0.1 | 0.3 | 0.6 | 0. | 0.8 | a. | 0.2 |
| -nties | 0.1 | 0.0 | 0.1 | 0.6 | 0.0 | 0.0 | 0.0 | 0.0 | 0.1 | 0.1 | 0.0 | 0.0 | 0.0 |
| -potroi | 0.2 | 0.0 | 0.3 | 0.4 | 0.0 | 0.0 | 0.1 | 2.1 | 0.4 | 0.1 | 1.1 | a. 2 | 0.1 |
| -toodproc | 0.0 | 0.0 | 1.8 | 0.4 | 0.0 | 0.0 | 0.1 | 0.2 | 1.4 | 30 | 1.9 | 0.3 | 0.6 |
| -brveram | 0.0 | 0.0 | 2.4 | 0.2 | 0.0 | an | 0.0 | 0.1 | a. 3 | 0.4 | 0.4 | 0.1 | 0.2 |
| vintmote | 0.0 | 0.0 | 0.0 | 0. | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| crearile | 0.0 | 0.0 | 0.0 | 0.1 | 0.0 | 0.0 | 0.1 | 0.0 | 0.5 | 0.3 | 0.3 | 0.1 | 0.1 |
| - -appera | 0.0 | 0.0 | 0.0 | 0.1 | 0.0 | 0.0 | 0.9 | 0.0 | 0.1 | 0.2 | 0.3 | Q. 1 | 0.1 |
| creatur | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| mpaper | a. 3 | 0.6 | 2.4 | 1.1 | 0.0 | 0.0 | 1.3 | 0.2 | 1.9 | 13 | 14 | 0.3 | 0.7 |
| -matrenical | 0.6 | 21 | 1.3 | 1.7 | 0.1 | 0.0 | as | 0.2 | 27 | 1.0 | 1.6 | 0.4 | 0.9 |
| mablar | 0.7 | 0.5 | 0.6 | 0.9 | a. 1 | 0.0 | 0.3 | 0.1 | 1.3 | 0.5 | 0.9 | 0.2 | 0.3 |
| cementime | 0.3 | as | a.s | 0.4 | 0.0 | 0.0 | 0.2 | 0.1 | 1.2 | 0.3 | 0.9 | 0.1 | 0.1 |
| Steriom | 14.5 | 26 | 0.6 | 1.7 | 0.2 | 0.1 | 0.3 | 0.3 | 2.1 | 0.7 | 10 | 0.1 | 0.1 |
| -monters | 0.7 | 31.3 | 0.4 | 1.1 | 0.1 | 0.0 | 0.1 | 0.1 | 1.3 | 0.6 | 0.6 | 0.1 | 0.1 |
| -umocturil | 23.9 | 15.8 | 14.9 | 3.2 | 0.6 | 0.2 | 0.4 | 0.4 | 1.5 | 1.4 | 1.4 | 0.4 | 0.6 |
| coserctaxa | 13.1 | 5.6 | 2.5 | 16.5 | 1.5 | 0.3 | 0.4 | 0.1 | 0.8 | 1.0 | 0.4 | 0.2 | 0.5 |
| enemocrect | 5.5 | 14.7 | 4.1 | 2.7 | 15.2 | 0.2 | 1.7 | 0.2 | 1.1 | 2.0 | 1.6 | 0.6 | 0.4 |
| Etrmext | 15.9 | 4.3 | 7.8 | 6.4 | 4.9 | 18.6 | 1.9 | 0.2 | 1.0 | 1.5 | 1.1 | 0.3 | 0.6 |
| mothmex | 1.1 | 3.7 | 1.1 | o. 5 | 1.3 | 0.0 | 5.3 | 0.1 | 0.3 | 0.5 | 0.5 | 0.2 | 0.3 |
| conomiter | 9.1 | 10.2 | 29.5 | 4.4 | 7.5 | 0.1 | 2.2 | 0.1 | 0.7 | 7.3 | 3.2 | 0.4 | 2.4 |
| melectic | 0.0 | 0.1 | 0.2 | 1.4 | 0.2 | 0.0 | 0.4 | 2.1 | 4.3 | 0.4 | 1.4 | 0.3 | 0.2 |
| -manumeroe | 0.0 | 0.0 | 0.7 | 0.5 | 0.4 | 0.1 | 22 | 1.2 | 7.5 | 1.4 | 6.1 | 4.7 | 5.9 |
| minacome | 0.2 | 0.2 | 0.4 | 1.0 | 0.8 | 1.6 | 0.8 | 1.4 | 1.3 | 0.0 | 3.9 | 0.9 | 1.1 |
| -4 | 0.0 | a, | 0.2 | 0.1 | 0.3 | 0.0 | 1.6 | 6.0 | 4.8 | 1.0 | 3.3 | 15.6 | 4.1 |
| cotheavi | 0.1 | 0.2 | 3.3 | 4. 8 | 5.3 | 1.4 | 16.5 | 2.6 | 4.3 | 5.8 | 11.1 | 5.9 | 9.0 |
| centid | 0.2 | 0.4 | 19.3 | 34.6 | \%.9 | 60.4 | 55.0 | 0.4 | 49.4 | 63.9 | 43.7 | 65.4 | 60.5 |
| maracom | 0.6 | a.s | 0.3 | 2.0 | 1.3 | 0.8 | 0.2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| row | 18.0 | 0.6 | 1.3 | 6.2 | Q. 6 | 8.8 | 8.3 | 0.0 | 0.2 | 4.3 | 8.7 | 20 | 1.3 |

Table 8, Cont.: Narth American Reosipt Shrens, 1988

## (proctance)

|  | menagriont | memining | mmpertel | madoodproc | mubieveras: | matobepo | neriertime | cmapparal | mudentar | mepaper | mancteatical | macrubber | marcomotam |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| cascom | 0.2 | 29 | 0.3 | 0.2 | 0.4 | 0.0 | 0.7 | 0.1 | 0.1 | 0.1 | 0.1 | 0.0 | 0.3 |
| Encom | 4.5 | 3.0 | 17.1 | 22 | 6.3 | 29 | 3.4 | 13.6 | 0.6 | 89 | 9.0 | 10.3 | 0.2 |
| mamagrical | 14.3 | 0.9 | 0.3 | 5.4 | 0.2 | 0.0 | 2.7 | 0.0 | 0.2 | 1.6 | 8.7 | 9.6 | 0.8 |
| umorimiag | 0.0 | 12.7 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.1 | 0.4 | 0.2 | 0.5 |
| memperol | 0.0 | 11.3 | 2.4 | 0.0 | 0.0 | 0.0 | 0.1 | 0.6 | 0.4 | 1.7 | 4.7 | 1.1 | 1.3 |
| madood proc | 378 | 0.1 | 0.1 | 12.4 | 0.0 | 0.0 | 3.4 | 0.0 | 0.0 | 23 | 1.1 | 1.2 | 22 |
| minbererap | 1.2 | 0.0 | 0.0 | 21 | 2.1 | 0.0 | 0.0 | 0.0 | 0.0 | 4.0 | 0.5 | 0.2 | 22 |
| unstotacos | 0.5 | 0.0 | 0.0 | 0.0 | 0.0 | 4.5 | 0.0 | 0.0 | 0.0 | 1.2 | 0.8 | 0.0 | 0.0 |
| manatile | 0.4 | 00 | 0.0 | 0.0 | 0.0 | 0.0 | 11.0 | 0.0 | 0.0 | 0.6 | 4.6 | 0.6 | 0.0 |
| nemeppered | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 20.3 | 0.4 | 1.0 | 1.7 | 20 | 1.7 | 0.0 |
| codetiter | 0.1 | 0.2 | 0.0 | 1.1 | 0.0 | 0.0 | 0.5 | 0.0 | 14.0 | 0.2 | 0.6 | 1.2 | 0.0 |
| coppepe | 0.1 | 0.0 | 0.0 | 0.2 | 0.0 | 0.0 | 0.1 | 0.0 | 0.0 | 19.9 | 1.0 | 0.2 | 0.0 |
| machenioal | 0.4 | 4.5 | 2.0 | 1.8 | 0.0 | 0.0 | 0.7 | 0.0 | 0.0 | 10.4 | 14.5 | 28 | 22 |
| marubber | 0.3 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.4 | 0.0 | 0.0 | 0.8 | 4.6 | 26 | 0.1 |
| manomamilil | 0.0 | 3.7 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 1.9 | 0.9 | 0.2 | 4.7 |
| metarom | 0.0 | 9. 1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.2 | 0.1 | 0.1 | 0.2 |
| macomberrit | 0.0 | s.a | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.2 | 0.5 | 0.3 | 0.0 |
| maxwoodreat | 2. | 1.2 | 0.0 | 0.0 | 0.0 | 0.0 | 1.5 | 0.0 | 0.1 | 1.4 | 1.7 | 1.4 | 0.6 |
| manaekomex | 0.0 | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.1 | 0.0 | 0.0 | 0.3 | 0.1 | 0.6 | 0.1 |
| medecaract | 0.0 | 1.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.1 | 0.0 | 0.0 | 1.5 | 0.6 | 3.5 | 23 |
| metrmegre | 0.0 | 0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.4 | 0.0 | 0.0 | 23 | 0.4 | 5.1 | 1.3 |
| coveliment | 0.1 | 4.4 | 0.1 | 0.0 | 0.0 | 0.0 | 0.7 | 0.0 | 0.1 | 2.5 | 0.4 | 1.3 | 0.9 |
| cmocertat | 0.0 | 18.7 | 0.2 | 0.0 | 0.0 | 0.0 | 0.8 | 0.0 | 0.0 | 2.5 | 2.3 | 63 | 43.5 |
| medeate | 0.0 | 0.0 | 1.4 | 0.0 | 0.0 | 0.0 | 0.0 | 0.1 | 0.0 | 0.6 | 0.3 | 0.1 | 0.2 |
| memonamice | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.1 | 0.0 | 0.0 | 1.3 | 0.1 | 0.4 | 0.0 |
| matimeosemin | 0.0 | 0.0 | 0.7 | 0.0 | 0.0 | 0.0 | 0.2 | 0.0 | 0.1 | 1.2 | 0.1 | 15.2 | 0.1 |
| umitime | 0.0 | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 22 | 0.3 | 0.1 | 0.5 |
| moctiown | 0.2 | 0.2 | 0.1 | 0.6 | 0.1 | 0.0 | 1.4 | 0.1 | 4.6 | 4.0 | 6.1 | 3.1 | 4.7 |
| comedts | 3.2 | 1.4 | 11.4 | 723 | 90.5 | 80.7 | 48. | 4.3 | 70.3 | 20.7 | 28. | 29.7 | 28. |
| row | O.s | 20.0 | 4s3 | 1.4 | 0.3 | 20 | 10 | 0.8 | 0.5 | 0.7 | 4.5 | 0.5 | 21 |
|  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| ancos | 0.3 | 0.2 | 0.4 | 27 | 1.7 | 1.3 | 1.2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| max | 4.9 | 27.1 | 15.0 | 8.6 | 57.7 | 23.7 | 20.4 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| menpicat | 0.4 | 0.4 | 2.0 | 1.7 | 0.1 | 0.5 | 0.4 | 0.0 | 4.1 | 23 | 1.9 | 24 | 0.5 |
| maxime | 0.2 | 0.0 | 0.4 | 0.3 | 0.1 | 0.3 | 0.0 | 0.0 | $2{ }^{1}$ | 0.3 | 0.3 | 0.7 | 0.3 |
| -patul | 5.3 | 0.8 | 1. | 15.6 | 1.0 | 0.4 | 0.7 | 0.0 | 20.2 | 4.4 | 0.5 | 22 | 7.3 |
| matoodprox | 0.0 | 0.6 | 1.4 | 0.5 | 0.0 | 0.2 | 0.0 | 0.0 | 2.0 | 3.7 | 3.3 | 0.7 | 0.7 |
| emberay | 0.9 | 0.1 | 14 | 0.2 | 0.0 | 0.1 | 0.0 | 0.0 | 1.0 | 0.8 | 0.4 | 0.4 | 0.6 |
| Troture | 0.0 | 1.5 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.1 | 0.2 | 0.1 | 0.1 | 0.1 |
| maxaxile | 0.0 | 0.2 | 0.2 | 0.1 | 0.0 | 0.1 | 0.0 | 0.0 | 1.0 | 0.7 | 0.6 | 0.3 | 0.2 |
| -xepperal | 0.0 | 0.1 | 0.2 | 0.0 | 0.0 | 0.0 | 0.1 | 0.0 | 0.3 | 0.4 | 0.6 | 0.5 | 0.2 |
| culath | 0.0 | 0.3 | 0.2 | 0.0 | 0.0 | 0.0 | 0.2 | 0.0 | 0.3 | 0.5 | 0.3 | 0.3 | 0.0 |
| mappap | 0.0 | 1.0 | 0.7 | 0.1 | 0.0 | 0.0 | 0.1 | 0.0 | 1.4 | 0.4 | 0.3 | 0.4 | 0.2 |
| conctersion | 0.0 | 1.7 | 1.1 | 0.4 | 0.0 | 0.2 | 0.0 | 0.0 | 0.7 | 1.8 | 1.6 | 0.6 | 0.5 |
| marubber | 0.1 | 0.3 | 0.2 | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 | 1.1 | 0.5 | 0.4 | 0.3 | 0.2 |
| urcomartme | 0.1 | 0.4 | 0.4 | 0.1 | 0.0 | 0.1 | 0.0 | 0.0 | 3.3 | 0.2 | 0.3 | 0.3 | 0.3 |
| mederrose | 14.7 | 0.7 | 1.1 | 0.4 | 0.1 | 0.2 | 0.0 | 0.0 | 24 | 0.4 | 0.4 | 0.1 | 0.2 |
| mancolern | 0.1 | 6.6 | 0.3 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 1.0 | 0.3 | 0.3 | 0.1 | 0.1 |
| marwostured | 11.5 | 7.9 | 10.8 | 0.4 | 0.1 | 0.1 | 0.1 | 0.0 | 1.8 | 1.7 | 1.3 | 1.0 | 0.5 |
| cranselamax | 2.0 | 2.8 | 0.7 | 21 | 0.1 | 0.7 | 0.0 | 0.0 | 0.3 | 0.4 | 0.3 | 0.2 | 0.1 |
| crumbecmech | 2.5 | 12.9 | 2.7 | 0.3 | 2.9 | 0.1 | 0.1 | 0.0 | 0.8 | 1.3 | 1.0 | 0.4 | 0.3 |
| metrmeatat | 5.1 | 4.0 | 1.3 | 0.3 | 0.2 | 14.6 | 0.1 | 0.0 | 1.1 | 1.5 | 1.2 | 0.6 | 0.9 |
| mothment | 0.3 | 3.5 | 0.6 | 0.1 | 0.1 | 0.0 | 2.2 | 0.0 | 0.4 | 0.7 | 0.5 | 0.4 | 0.1 |
| mexcoentret | 37.4 | 9.4 | 16.4 | 3.5 | 1.4 | 0.0 | 0.2 | 0.0 | 2.2 | 3.2 | 5.1 | 4.2 | 3.2 |
| medectic | 0.1 | 0.1 | 0.3 | 0.2 | 0.4 | 0.1 | 0.1 | 0.0 | 7.9 | 0.9 | 0.4 | 0.4 | 0.5 |
| ancoumamior | 0.0 | 0.1 | 0.1 | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.7 | 0.2 | 0.4 | 0.9 | 0.7 |
| Lextrecome | 0.0 | 0.6 | 0.4 | 0.7 | 0.2 | 4.9 | 0.1 | 0.0 | 1.3 | 1.7 | 5.6 | 1.4 | 4.1 |
| mativisum | 00 | 0.1 | 0.2 | 0.0 | 0.0 | 0.0 | 0.3 | 0.0 | 1.7 | 0.3 | 0.4 | 12.6 | 2.5 |
| modiers | 0.0 | 1.2 | 1.7 | 1.3 | 1.1 | 3.0 | 1.7 | 0.0 | 3.0 | 2.0 | 2.5 | 7.4 | 6.6 |
| merextd | 6.1 | 13.0 | 37.4 | 50.0 | 27.4 | 42. | se.s | 100.0 | 20.7 | ces | 61.3 | 60.4 | 0.1 |
| row | 1.9 | 1.6 | 0.5 | 1.1 | 8.5 | 6.3 | 3.7 | 0.0 | 0.0 | 00 | 0.0 | 0.0 | 0.0 |

Table 9: Intercountry Multipliers, 1988: Multiplier Analysis I $^{a}$ (cents per dollar of new demand)

| Sector | $\mathrm{N}_{2}(12)$ | $\mathrm{N}_{2}(13)$ | $\mathrm{N}_{2}(21)$ | $\mathrm{N}_{2}(23)$ | $\mathrm{N}_{2}(31)$ | $\mathrm{N}_{2}(32)$ |
| :---: | ---: | ---: | ---: | ---: | ---: | ---: |
| agricult | 0.7 | 0.4 | 6.8 | 9.5 | 0.2 | 0.9 |
| mining | 0.8 | 0.5 | 17.3 | 3.5 | 1.0 | 0.5 |
| petrol | 6.8 | 0.2 | 5.1 | 3.8 | 0.5 | 3.1 |
| foodproc | 0.7 | 0.3 | 7.1 | 4.9 | 0.2 | 0.3 |
| beverags | 1.0 | 0.0 | 1.5 | 0.4 | 0.3 | 0.6 |
| tobacco | 0.1 | 0.0 | 1.3 | 0.2 | 0.0 | 0.1 |
| textiles | 0.9 | 0.2 | 26.7 | 14.6 | 0.6 | 0.3 |
| apparel | 0.5 | 0.1 | 2.0 | 10.3 | 0.1 | 0.7 |
| leather | 0.2 | 0.0 | 13.0 | 11.5 | 0.3 | 1.5 |
| paper | 6.1 | 2.1 | 10.3 | 25.2 | 0.0 | 0.3 |
| chemical | 0.4 | 0.1 | 25.3 | 14.8 | 0.2 | 0.8 |
| rubber | 1.0 | 0.5 | 24.3 | 35.4 | 0.1 | 0.4 |
| nonmetmn | 0.5 | 0.1 | 12.5 | 3.2 | 0.2 | 0.0 |
| ferrous | 2.3 | 1.0 | 9.8 | 11.0 | 0.3 | 0.5 |
| nonferrs | 4.9 | 0.8 | 26.7 | 24.1 | 0.3 | 1.4 |
| woodmetl | 2.8 | 0.4 | 13.0 | 14.9 | 0.2 | 0.6 |
| nnelcmac | 2.5 | 1.9 | 48.0 | 57.1 | 1.0 | 0.5 |
| elecmach | 1.4 | 0.9 | 33.8 | 54.8 | 1.5 | 2.2 |
| trnseqpt | 14.1 | 3.4 | 46.0 | 22.5 | 0.8 | 1.3 |
| othmanuf | 1.9 | 0.2 | 19.3 | 7.6 | 0.5 | 0.9 |

Note: ${ }^{a} N_{2}(i j)$ denotes the additive inter-country multiplier effect of changes in exogenous demand for the sector in region $j$ on income of the sector in region $i$. County codes are $1=$ Canada, $2=$ United States, and 3=Mexico.

Table 10: Intercountry Multipliers, 1988: Multiplier Analysis II ${ }^{a}$
(cents per dollar of new demand)

| Sector | $\mathrm{N}_{2}(12)$ | $\mathrm{N}_{2}(13)$ | $\mathrm{N}_{2}(21)$ | $\mathrm{N}_{2}(23)$ | $\mathrm{N}_{2}(31)$ | $\mathrm{N}_{2}(32)$ |
| :--- | ---: | ---: | ---: | ---: | ---: | ---: |
| agricult | 2.6 | 1.6 | 19.8 | 25.9 | 1.2 | 2.5 |
| mining | 1.8 | 1.1 | 20.3 | 5.3 | 1.2 | 0.7 |
| petrol | 9.8 | 1.6 | 18.9 | 19.0 | 1.0 | 4.2 |
| foodproc | 3.4 | 1.9 | 27.4 | 27.4 | 1.1 | 1.9 |
| beverags | 1.5 | 0.2 | 4.8 | 3.8 | 0.5 | 1.0 |
| tobacco | 0.2 | 0.1 | 3.2 | 2.0 | 0.0 | 0.2 |
| textiles | 1.5 | 0.6 | 33.2 | 22.2 | 0.8 | 0.5 |
| apparel | 1.0 | 0.4 | 6.2 | 16.9 | 0.2 | 1.0 |
| leather | 0.2 | 0.1 | 13.8 | 13.3 | 0.4 | 1.6 |
| paper | 9.6 | 4.0 | 26.0 | 42.7 | 0.3 | 0.7 |
| chemical | 1.9 | 0.9 | 40.6 | 29.0 | 0.7 | 1.6 |
| rubber | 1.7 | 0.9 | 34.0 | 46.4 | 0.3 | 0.7 |
| nonmetmn | 1.0 | 0.4 | 17.9 | 8.2 | 0.3 | 0.2 |
| ferrous | 3.3 | 1.4 | 15.5 | 15.1 | 0.5 | 0.9 |
| nonferrs | 5.9 | 1.4 | 33.6 | 30.4 | 0.5 | 1.7 |
| woodmetl | 6.1 | 2.1 | 35.1 | 35.5 | 0.5 | 1.2 |
| nnelcmac | 4.4 | 3.3 | 64.6 | 72.2 | 1.4 | 0.9 |
| elecmach | 3.1 | 2.1 | 59.8 | 84.2 | 2.1 | 3.1 |
| trnseqpt | 23.2 | 7.6 | 80.6 | 45.2 | 1.6 | 2.2 |
| othmanuf | 2.8 | 0.7 | 26.8 | 14.2 | 0.6 | 1.1 |

Note: ${ }^{a} N_{2}(i j)$ denotes the additive inter-country multiplier effect of changes in exogenous demand for the sector in region $j$ on income of the sector in region $i$. County codes are $1=$ Canada, $2=$ United States, and 3=Mexico.

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|  | Association, Vol. 18, No. 4, 1990 |


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# Outline of 1985 Japan-U.S. $E C(a g s$ egated three countries) <br> International Input-Output Table 

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## Introduction

The Ministry of International Trade and Industry (MIT) started preparing in 1986 the 1985 International Input-output Table. So far, MITI has prepared and released the 1985 JapanU.S. International lnput-Output Table (163 sector classifications, 46 sector classifications, 26 sector classifications), 1985 Japan-U.K. International Input-0utput Table (93 sector classifications, 43 sector classifications, 24 sector classifications), 1985 Japan-France International Input-Output Table (86 sector classifications, 43 sector classifications, 24 sector classifications) and 1985 Japan- Mest Gerany International InputOutput Table (55 sector classifications, 43 sector classifications, 24 sector classifications) as bilateral international input-output tables.

As of Noveaber 1992, we are currently engaging in preparing and conpiling the 1985 Japan-U.S. $-E C(i n t e g r a t i n g ~ t h r e e ~ c o u n t r i e s) ~$ International Input-output Table. As soon as we complete this. we plan to prepare and compile the 1985 Japan-U.S.-EC(integrating three countries)-Asia International Input-0utput Table, which links the Asia International Input-0utput Table integrating eight Asian countries and regions. The Asia lnternational Input-0utput Table was prepared by the Institute of Developing Econonies of Japan.

This paper primarily explains the nethod used to conpile the 1985 Japan-U.S.-EC(integrating three countries) International Input-output Table. Ve $i l l$ prepare and explain sore analytical results using the table when we me progress in preparation of the table which we are currently (Novener) undertaking.

1. Outline of Conplling the 1985 Japan-U. S. - EC (Integrating three countries) International Input-output Table

The outline of the 1985 Japan-U.S.-EC (integrating three countries) International Input-0utput Table compiled by MIT is as follows:
(1) covering 1985 ,
(2) covering Japan. U.S., EC (integrating three countries:
U.K., France, Mest Gerany),
(3) providing comion sectoral classification into 49
sectors,
(As bilateral tables break dorn sectors into more detail than the 1985 Japan-U.S.-EC table, they allor relatively more detail inter-sectoral analysis. Bilateral tables prepared by MITI are the nuber of sectors as follows:
(a) 1985 Japan-U.S. table (163-sector, 46-sector, 26-sector),
(b) 1985 Japan-U.K. table (93-sector, 43-sector, 24-sector),
(c) 1985 Japan-France table (86-sector, 43-sector, 24-sector),
(d) 1985 Japan-fest Germany table (55-sector, 43-sector, 24-sector).
(4) providing a table non-conpetitive inport type,
(5) providing a table at producers' price (except imports of C.l.F. value fror Rest of the Morld),
(6) expressing in dollars by the annual average exchange rate for 1985 ( 238.54 yen/dollar ; 0.7714 pound/dollar ; 8.9852 franc/dollar ; 2.9440 ark/dollar )
2. The Procedure for Conpilling the 1985 Japan-U.S.-EC (integrating three countries) International Input-output Table

### 2.1 The Input-output Iables Ie Used

(1) the 1985 input-output table of Japan:

Basic table by 11 -Ministries and Agencies of Japan ( prepared every 5 years for years ending with a or 5 ); Publication by Manaerent and Coordination Agency of Japan;

Consodity by Consodity table;
size: row 529 * colum 408-sector;
producer's price
(2) the 1985 input-output table of U.S.:

Extended table by Interindustry Econoic Research Fund Inc. of University of Maryland of U.S. on the basis of 1982 Basic table (Departaent of Conerce of U.S.A.
( Notice: used the 1985 U.S I-O Table based on 1977 for the 1985 Japan-U.S. bilateral l-O Table );

Consodity by Conmodity table;
size: ron 540 * colum 540-sector, producer's price
(3) the 1985 input-output table of U.K.:

Publication by Central Statistical Office of U.K.;
Conaodity by Conaodity table;
size: rom 102 * column 102-sector. producer's price
(4) the 1985 input-output table of France:

Publication by INSEE of France;
Connodity by Connodity table;
size: row 98 * column 98-sector.
purchaser's price
( table format of balancing is expressed by total demand on
the row sector (horizontal direction of the table) equal total supply on the coluan sector (vertical direction of the table), and iaports showed belor value added iteas. )
(5) the 1985 input-output table of Vest-Cerany:

Publication by Federal Statistical Office of Vest-Gerany; Connodity by Connodity table;
size: row 58 * coluen 58-sector.
producer's price
(6) bilateral international input-output tables:
the 1985 Japan-U.S. international input-output table (163-sector, 46-sector, 26-sector).
the 1985 Japan-U.K. international input-output table ( 93-sector, 43-sector, 24-sector),
the 1985 Japan-France international l-0 table ( 86-sector, 43-sector, 24-sector). the 1985 Japan-lest Germany international l-0 table (55-sector, 43-sector, 24-sector),
Publication by MITI of Japan;
Comedity by Commodity table;
producer's price

Notice:
These tables are used as reference for the 1985 Japan-U.S.-EC (integrating three countries) I-0 table.

Vhen preparing bilateral international input-output tables, there is only one objective trading partner. Therefore, it was possible to establish the coanon sector classification by adjusting Japanese $\mathrm{I}-0$ table sectors to the sector classification of the trading partner's l-0 table in order to establish as many comen sector classification as posible.

On the other hand, ultilateral international inputoutput table has several trading partners. For this reason, the classification of Japanese l-0 table cannot be natched to one specific objective country's sector classification.

The fact that there is also lack of data and inforation such as production value, input value, output value ( = breakdonn of distribution of products and iaports to each purchaser) to be used to adjust sector classification of the objective country's i-0 tables were taken into consideration.

Accordingly, comen sector classification for the 1985 Japan-U.S.-EC (integrating three countries) l-0 table $\begin{aligned} \text { as }\end{aligned}$ established by way of comparing crossinse each objective country's $\quad-0$ sector classification as well as properly integrated.

### 2.2 Basic Vorking Procedure

### 2.2.1 Exaifation of Basic Matters

Te had exanined the basic natters such as schedule, working procedure, table forat, hor to estiate, and so on.

### 2.2.2 Compilation of The Connon I-O Sector Classification

Me had established provisional a conmon I - sector classification for the 1985 Japan-U.S. $-E C$ (integrating three countries) l-O table by mainly integrating sectors. After checking the concepts and consodities of each national l-0 table's sector, we had adjusted refine tuning within feasible limits men re thought me should do so.

```
2.2.3 Preyious Adjustaent of Each National I-O Table ( Japan, U.S., U. \({ }^{\text {Pe, France, Mest-Geriany ) }}\) for Standardiation of Table Fornat
```

Each country akes its $1-0$ table according to its policy, reflecting its economic structure. There are many differences
auong these tables. Therefore, each country's l-0 table had to be adjusted for standardiation of table forat beforehand linking Into a nultilateral table.

These details are shown in 3 . Adjustant of Each Country's l-0 Table to Carry Out Standardization of Table foratn.

### 2.2.4 Estiation of the trade sectors

Me estiated figures of the trade sectors after the abovenentioned adjustrent in order to link each national l-0 table into a cultilateral l-0 table. This estination of trade sector is essential mork for making clear the industrial interdependence anong countries, mhich the donestic l-O table of each country could not do so far. The trade sectors anong Japan, U.S., EC (integrating U.K., France, lest-Gerany) and these country's exports to the Rest of the lorld countries (R.0.l) rere estinated by producer's price, and these country's imports fron R.O.l. were estiated by C.I.F. (Cost of lnsurance and Freight) price.

Estination of trade sectors is mainly based on the inforaation of iaports. Re nainly estirated each objective country's import matrix conmodity by country, which estimated fron the objective country's original inport atrix (CIf price; fronall over the rorld) and fron colun vector of iaports divided into each objective country using the inport country's ratio of inport statistics. We also applied withinfeasible linits for the estiation the results of the special survey of "Deand Structure of Japanese Exported Goods" and "Deand Structure of Japanese laported Goods" on business groups and trading companies in Japan.

As me had to estinate the import ratrix pron the objective countries by original country's producer's price, both of the international freight and insurance and the donestic freight argin mithin objective country were reaved fron iaport value. The international freight and insurance were entered into same nare item as row vector in the rable. Custon duty and other import tax were also entered as vector into iten of custon duty
and import tax". And the donestic freight margin within objective country were also entered as a row vector into nomestic freight marsin from import country".
2.2.5 Balancing

The colum sum and the row sum of each sector should balance in the 1985 Japan-U.S.-EC (integrating three countries) $\quad 1-0$ table. But due to previous adjustaents, itay lose its balance, so ve had to again readjust the balance.

Discrepancy between export country's figures (producer's price) and import country's figures (producer's price) are entered into "Adjustment Iten" which includes going on transporing export goods to import country and other discrepancy factors.
3. Adjustment of Each Country's I-O Table to Carry Out Standardization of Table Format"
3.1 Adjustrent of Japanese I-0 table
3.1.1 Adjustment of Special Sectors Peculiar to Japanese I-0 Table

Unless such previous adjustments aremade topanese $1-0$ table, the concept of each column sector's production value of Japan will conflict with the other objective countries (Notel). In addition, when comparing the "manufacturing industry" with the "non-manufacturing industry", for instance, all reaining sectors of industries other the mantacturing industry $\begin{aligned} & \text { ill be counted as }\end{aligned}$ "non-manufacturing industry" sectors and distort the results of comparison.
[ Note ]: While self-activities sectors are included in each colum sector of the other objective countries, these sectors are
not included in Japan and reported collectively in independent sectors.]
(1) Deletion of colunn/ron vector of self-activities sec tors (self-transport, self-education, self-study such as inhouse R\&D) of endogenous sector, and addition to the endogenous sector by, forming atrix of the mentioned sector (vector).
(2) Deletion of colunn/ron vector of duny sectors (office supplies for business use) of endogenous sector, and addition to the endogenous sector by forming atrix of the uentioned sector (vector).
(3) Make endogenous the columiron vector of the consump tion expenditure outside household" (= business consumption) of the exogenous sector in Japanese l-0 table.

Make sector endogenous with column/row vectors without foraing a matrix.
The reasons are as follow:
i) The "consumption expenditure outside household" (= business consumtion) sector is a sector peculiar to Japan.
ii) The weight of corporate entertainent expenses of the broken down itens is substantial,
iii) Corporate entertainment expenses ridely fluctuate with trends in business conditions,
iv) If the sector is foraed into a atrix and added to each production sector, it becomes isleading when perforaing an international comparison of production technology structure.

### 3.1.2 Adjustins Scope of "Goyernuent" Sector

 And Exosenous Processing the SectorThe nev SNA (Systen of National Account) treats the government sector (governent affairs, national and public schools and hospitals etc.) as "producer of government service activity".
In Japanese l-0 table, "interadiate input value + value added amout = production value ( $=$ total expenses without operating surplus)" is entered on the input side, wile on the output side the entire remaining anount less sale to the household and other sectors is entered in "governaent final expenditure".
France and lest Gerany also treat the table forat in the same nanner.

Horever, U.S. I-O table does not confora to the ner SNA.
Thus, lt treats the "governaent affairs" sector priarily as a consumption sector. Nevertheless, it is necessary to enter conpensation for governaent employes. Therefore, a ${ }^{n}$ governent affairs" sector is created for convenience in the endogenous sector, and "conpensation for employes = ralue added = production valuen is entered on the input side, while on the output side the entire anount is entered in "governant purchase" (goyernaent final consumtion expenditure + fixed capital foration (governaent)).
U.K. adopts a table forat sinilar to that of the U.S..

But "conpensation for employees" as vell as "corporate incore" (operating surplus + depreciation of fixed capital) and "indirect taxes" are mentioned in the colum rector on the value added side.

For this reason, the table forat of each country's 1-0 table and reporting athod of the ${ }^{\text {ngovernaent affairs" sector }}$ must be standardized anong Japan, U.S., and EC (U.K., France. West-Germany).
If not, the production value of the "governaent affairs" sector and its structure of expenses ill reain in disagreanent, thus giving rise to inconvenience. In addition, with respect to analysis, the structure of the coluan vector of ${ }^{\text {g governaent final }}$
consumption expenditure" on the final denand side for "Japan-EC (integrating U.K., France, Hest-Germany)" will greatly differ fros that of the "U.S.". As a result, international comparison of the induced production ralue by final deand items ill be hindered.

Examples of adjustrent of japanese l-0 table are presented belon. U.K., France, and Test Germany also made sirilar adjustsents.
(1) The name is "government activities" sector, and the scope covers only "governaent affairs" sector.
The scope of each country's "government affairs" sector is in accordance ith the scope of definition of each country's I-0 tables.

However, U.K. $\quad 1-0$ table presents the sector as a "government affairs and others" sector which cannot be divided.
(2) The description method of the "government activities" sector will adopt the U.S. I-0 table aethod. Each country's l-0 tables will be adjusted. The interaediate input colun vector, homever, will be transferred to the norernaent purchase" column vector on the final derand side.
But the colun vector on the value added side will continue using the description rethod of each country's l-0 tables.
(Reasons)
(i) Inforaation to me endogenous the "government activi ties" sector of the U.S. I-0 table is unavailable.
(ii) In order to enable international comparison of induced production ralue by final deand iters, there is no choice but to adjust the table format of the "government activities" sector to U.S. I-0 table.
(iii) Regarding the value added portion of governaent affairs, the views of each country l-0 table will be given serious consideration.
(3) Among the column vectors of the "governant affairs" sector of Japanese l-0 tables.
(i) The "interaediate input valuen portion was added and reported in the "governeent purchasen colum vector ( = "governent final consumption expenditure" + "gross donestic fixed capital foration (governaent) ) of final deand by parallel displacerent to the final deand side.
( O is assigned to interaediate input of the governaent affairs sector.)
(ii) The value added portion of the "governaent affairs" sector vas adjusted so that "coapensation for eaployees". "depreciation of fixed capital", "indirect taxes", "total value added" $=$ "total dorestic products".
[ Note: The value added portion of governaent affairs ras left as described by each country's l-O tables. ]

Amon the row vectors of the "governaent affairs" sector,
(i) The "interaediate deand value" portion was set at 0.
(ii) The "final deand value" portion was reported in "private consumption expenditures" and "governaent purchase" (coluen rector).
[Note: The final deand portion of governaent affairs mas left as described by each country's l-0 tables.]
(4) Among the final deand sectors,
"governaent final consunption expenditure" (column vector) and ${ }^{n} g r o s s$ donestic fixed capital foration (governaent)" (column vector) were integrated and treated as "governaent purchase" (column vector).

```
3.1.3 Adjustaent of Specific_Sectors of Japanese l-0 Tables
        to Establish Conmon Sectors
    (1) "Copying rachine":
    separated fron "nachine for business use" sector (3111-01)
--> transferred to "other optical Eachine" sector (3711-09).
(2) "Industrial transport vehicle":
    separated fron "other transport nachinery" sector (3629-09)
--> transferred to "transport machinery" sector (3012-01).
(3) "Magnetic tape (blank)":
    separated fror "parts and accessories of electric acoustic
    instrusent" sector (3431-03)
--> nerly established "agnetic tape (blank)".
```

3.2 Adjustaent of U.S. I-O tables
3.2.1 Adjustnent of special sectors peculiar to U.S. I-O Table
(1) Deletion of "Rest of the llorld Industry" sectors (iteas to be balanced with GNP statistics)
(2) Make sector endogenous by treating exogenous sector's "unimportant industry" sector as "activities not elsemhere classified" sector.
(3) Make sector exogenous by row vector of endogenous sector's "royalty" sector, deletion of colum.
(i) Add row vector to "opérating surplus" on value added side,
(ii) Delete colun vectore Along ith this adjustant, deduct the amount reported in the intersection point of the "royalty" sector (ron) and export (coluan) and the aentioned a■ount fros the value added side of the "royalty" sector.
(4) Estiration of "custor duties" coluan rector and deduc tion fron "inport" column vector.
(5) Transfer processing of positive value of freight to be paid to domestic transit conpany reported in intersection point of the ron's "nater transport" and colunn's "inport" to "export" (colum).

### 3.3 Adjustment of U.I. I-O table

3.3.1 Adjustent of special sectors peculiar to U. $\mathbb{Z}$. I-O Table
(1) Separate indication of non-deductible value-added tax".
(2) Separate indication of "custon duties" vector.
( For estiation of custon duties on Japan vector and Rest of the lorld custon duties vector.)
(3) Reporting of "individual conadity tax" to production sector.
( Alcoholic drink tax, cigarette tax, oil tax, auto tax, garbling tax, gas tax will be reported to production sector. )
(4) Make endogenous the "saile by final deand sector" sector on the value added side.

```
3.3.2 Adjustrent of Specific_Sectors Pecullar to U.I. I-0
Tables to Establish Comson Sectors
(1) "Coal/coal products" sector: divide (estinate) into "coal" (aining) and "coal products" ( Eanufacturing industry).
(2) Conaerce and repair" sector:
--> divided (estiate) into "conerce" (conerce) and "Repair" (service industry).
(3) "Hotel and restaurant" sector: reaval of "trade argins".
(4) "Private ilnal consumption" sector: --> divide into "final consurption of households" and "final consumption of non-profit organizations".
```

3.4 Adjustrent of French l-0 table
3.4.1 Adjustaent of Special Sectors Peculiar to French l-0 Table
(1) Total deand = convert total supply balance table into allocated production value table.
( To adjust to table format of the other objective country's l-0 tables and enable international conarison. )
(2) Convert ${ }^{\text {n }}$ input-output table at purchasers price" into "input-output table at producers' price."
( To adjust to table forat of the other objective country's 1-0 tables and enable international conarison. )
(3)

Collective reporting of "inputed interest"
--> convert and estiate into ron vector and allocate to
endogenous sector.
( In order to adjust to the table forat of Japanese l-o table, "imputed interest" reported collectively in the intersection point of the "financial" sector of the row and "BUF" sector of the colum of the French 1-0 table (Note 1) mill be converted and estiated into the endogenous sector's colum vector. )
[ Note l: The duary sectors have the functions of $c$ ) as well as the function to convert the donestic concept into a national concept.]
(4) Processing and adjustaent of three "transfer" sectors (row vector on value added side):
(i) Deletion of TRII (transfer of by-product) sector:
--> convert by-product into description in ${ }^{n}$ negative input aethod" and report in endogenous sector.
"By-product atrix" of internal materials mas used and converted into the negative input nethod by reporting it as a negative entry in the intersection point of the generation sector coluan and priary production sector row.
(ii) Deletion of TR12 (transfer of research service):
--> adjust the transfer processing (scalar) of secondary research service (Note 2) to the "education/research service (industry)" sector -- a processing method unique to French l-0 tables -- to the description athod of activity base of Japanese l-0 table, and convertinto a form were it is transferred to the "education/research service (industry)" sector by colum vectors. In estiating the coluan vectors, the input coefficient the neducation/research service (industry)" sector was used.

The colum vectors corresponding to the transfer value
(scalar) transterred fron each coluan sector which undertook sale of the mentioned service rere renoved and added to the column vector of the "education/research service (industry)" sector.
['Note 2: Incore derived fron sale of a portion of in-house research services included in each industry sector to other industry sectors.]
(iii) Deletion of TR13 (transfer of existing sale of general governaent and private non-profit organizations):
$-->$ In French $I-0$ table, the general governaent and private non-profit organizations sell to other sectors goods and services remaining, besides production of non-market services. But it treats these services as secondary products and transfer (scalar) thea to colume sectors, whose primary products are goods and services.

In order to adjust this transfer processing (scalar) to the activity-based description aethod of japanese $\quad 1-0$ tables, the column vector was estinated by using the input coefficient of the place of transfer as in if abovementioned and added to each production sector of the place of transfer.
[ Reference:
The three row vector sectors for transfering the exogenous sector on the value added side of french $1-0$ table ain at transfering by-products and secondary products from the generating sector to the sector whose primary products are the aboverentioned products. These sectors are reported in the generating sector as a negative itemand in the transfer sector as a positive iten. ]
(5) Deletion of PCHTR sector and BUF sector (Note 2) of dubuy sectors
[ Dungy sectors to convert "consumption of households." from a douestic concept into a national concept ]
(6) Net input-output table --> preparation of adjusted net input-output table.
(Reason):
French l-0 tables are published in net input-output tables ( table fornat where non-deductible value-added taxes are included in each cell).
International conparison in the tables without tax is taken into consideration, and tables ithout tax of internal aterials are used and deducted from net input-output tables to prepare non-deductible value added tax matrix.
The rom vector formed by the column sum of this, matrix is treated as " non-deductible value added tax" and reported in the ralue added sector of the table without tax.
3.4.2 Adjustrent of specific sectors of French l-0 table
(1) "Auto sale and repair" sector:
--> divide into "auto sale" (comerce) and "repair (service industry).
(2) "Collection industry" sector:
$-->$ nemly establish and transfer activities not else where classified" sector.
(Reason):
Japanese l-0 tables handle scrap and by-products with the negative input wethod. But French l-0 tables deal with
these products by creating "collection industry" sector ( processing to collect and recycle scrap).

Thus, it is difficult to take the sare aeasures as this sector.
(3) Xake exogenous "government affairs" sector.

### 3.5 Adjustrent of Iest Gerian l-O table

### 3.5.1 AdJustrent of Specific Vest Geran l-O Tables to Establlsh Conson Sectors

(1) Allocation and estination of "imputed interest" to endogenous sector.
(2) Allocation and estiation of "coal" (nining) anc "coal products" (nanufacturing industry) fron the "coal/coal products" sector.
(3) Kake exogenous "government affairs" sector.

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## National Accounts, SNMs and SESAME:

a Systen of Bcononic and Social Accounting Matrices and Extensions
with an application to the case of Indonesia

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## Abstract

The revised, 1993 System of National Accounts (SNA) will contain a chapter on Social Accounting Matrices (SAMs), demonstrating that the Input-Output approach can be extended to a matrix presentation of a wider set of national accounts. This paper elaborates on some of the themes in that chapter and describes its application to the case of Indonesia.

First, some general principles of matrix accounting are set out. It appears that a matrix is typically more flexible than other formats for presentation; in each account, a unit and a classification of units can be selected that are most relevant to the set of economic flows under consideration.

Secondly, the essence of the SAM-approach is that it shows the entire circular flow of income at a meso-level. For that purpose, special attention should be paid to the classifications in each account. In this paper, some general principles are discussed and illustrated with the help of a SAM for Indonesia.

Finally, the linkage of a SAM to all kinds of supplementary (nonmonetary) data sets is outlined. This should yield a Systen of Economic and Social Accounting Matrices and Extensions (SESAME), that is, a consistent meso-level information system from which a set of main economic and social macro-indicators can be derived. By way of example, detailed employment figures that belong to a SESAME for Indonesia are presented.
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## 1. Introduction

This paper serves to provide a general introduction to the Social Accounting Matrix (SAM) and its elaboration to a somewhat broader System of Economic and Social Accounting Matrices and Extensions (SESAME). ${ }^{1}$ Our point of departure is the theory and practice of national economic and social accounting. Parts of this paper can also be found in the provisional version of the revised System of National Accounts (SNA) [United Nations, 1992: chapter XX]. ${ }^{2}$ Other parts of that SAM-chapter have been amended or deleted here as this text is meant to be selfcontained and focuses on an application to the case of Indonesia. ${ }^{3}$

A SAM is defined here as:
A presentation of economic accounts in a matrix that adopts in each account a unit and a classification of units which are most relevant to the set of economic flows (or stocks) under consideration. Evidently, this relevance also depends on the intended uses of the SAM. To date, most SAMs have been oriented towards an analysis of interrelations between structural features of an economy and the distribution of incomes and expenditures among household groups. A distinguishing characteristic of all SAMs, except the very aggregate ones, is that they show the entire circular flow of income at a mesolevel. ${ }^{4}$

This is illustrated for the case of a closed economy in figure 1 . The interdependence between production, income generation and distribution, and consumption expenditure is well-known, but figure 1 recalls that in

[^33]these processes different types of economic agents are involved: production in business units (in SNA terms: establishments) generates value added payable to primary inputs, that is employed persons and various types of productive assets (land, financial assets, etc.). In turn, these incones generated in production are handed over to institutional units such as households, corporations and the government. After a re-distribution process, the incomes are used for final consumption expenditure of products or saved. The circle is closed when the consumption of products again leads to production in business units.

Figure 1: Flow chart of the aconomic cyeles for a closed economy, es represented in asm

current Economic cycle
A correct representation of this simple economy requires the distinction of four types of statistical 'units': 1. products, 2. establishments, 3. primary input units (employed persons, cultivated hectares of agricultural land, etc.) and 4. institutional units (e.g. households, corporations and government units). It is clear that individual units cannot be presented in a nation-wide statistic. Instead, units should be classified in categories so that the interrelations between these subgroups can be shown and analyzed. This is done in a SAM. In fact, it can only be done in a matrix framework, since that allows for multiple actoring, that is, distinguishing nore than one type of unit within a single accounting system, and aultiple sectoring, that is distinguishing more than one classification of units within a single accounting system.

It stands to reason that most SAMs start from the conventions and definitions as laid down in the SNA. In fact, it is very well possible and perhaps even desirable to estimate the internationally standard national accounts on the basis of a SAM. In addition, there are
applications of the SAM-format whereby these rules are more or less amended, for instance because more stress is laid on the role of people in the economy. ${ }^{5}$


#### Abstract

Before an attempt is made to sketch a SAM and its elaboration to a SESAME, it seems appropriate to provide an elementary explanation of accounting matrices and their properties. To this end, section 2 highlights the uses of a matrix presentation for national accounts. Section 3 then introduces the SAM-concept by explaining the structure of the SAM for Indonesia. Section 4 dwells on the important topic of classifications for use in a SAM. Again, the Indonesian case serves to illustrate this point. How this works out in more detailed SAMs for Indonesia is shown in section 5. Finally, section 6 describes how a SAM can be linked to all kinds of monetary and non-monetary satellite tables, to arrive at a broader System of Economic and Social Accounting Matrices and Extensions (SESAME). A SESAME is meant to provide a flexible and comprehensive, yet fully consistent data frasework for socio-economic analyses.


## 2. Presenting national accounts in a matrix

This section elaborates on the general purposes that can be served by an accounting matrix. A crucial feature is the wide range of possibilities for expanding or condensing such a matrix in accordance with specific circunstances and needs.

Table 1 presents a number of consolidated transactions and balancing items for the Indonesian economy in 1980. Five types of accounts are distinguished: supply and use of goods and services, production, generation of income, distribution and use of income, and capital transactions. In the last account, all these transactions with the rest of the world (ROW) have been combined. The code numbers behind and below each account heading serve to facilitate the linkage of all tables in

[^34]| codes | $\left\|\begin{array}{l}\text { Goods and } \\ \text { services } \\ \text { Prockut } \\ \text { Groups) }\end{array}\right\|$ | Production (Industries) |  | Distribution and Use of Income (Institutional Sectors) | $\left\|\begin{array}{c}\text { Capital } \\ \text { (Institurtional } \\ \text { sectors) }\end{array}\right\|$ | Rest of the World (RON), Current and Capital | total |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | 11 | 121 | 131 | 42545 | 171 | 10811 |  |
|  | $\begin{gathered} \text { Trade and } \\ \text { Terapport } \\ \text { Margina } \\ 0.0 \end{gathered}$ | $\begin{array}{r} \hline \begin{array}{l} \text { Intermediate } \\ \text { Consumption } \\ 30.0 \end{array} \end{array}$ |  |  | $\begin{gathered} \text { Gross } \\ \text { CCpittel } \\ \text { Formetion } \\ 11.9 \end{gathered}$ | Exports <br> 16.2 | 89.2 |
|  | ourput |  |  |  |  |  | 79.0 |
| 3 |  |  |  |  |  | compensation of Employees from Row 0.0 | 49.1 |
|  | $\left\|\begin{array}{c}\text { Teves on } \\ \text { Production } \\ \text { sibacidice } \\ 0.3\end{array}\right\|$ |  | GROSS GENERATED <br> IMCOEN, ot <br> foctor coat <br> 49.1$\|$ |  |  | Property Income 2Current Trane fors from roil | 62.4 |
|  |  |  |  | Gross sAvIME <br> 15.3 | $\left.\begin{aligned} & \text { cepital } \\ & \text { rematers } \\ & \text { Tren } \end{aligned} \right\rvert\,$ | Cepital Trensfers from ROW 1.2 | 17.7 |
| $\text { (nou) }\left\|\begin{array}{c} -0 \\ 110 \end{array}\right\|$ | Imports $9.9$ |  |  |  | met Lewolma <br> of the mation <br> 4.6 |  | 17.5 |
|  | 89.21 | 179.01 | 149.1 \| | $1 \quad 62.41$ | 17.71 | \| 17.5 |  |

this paper. ${ }^{6}$ In each of these tables, the boxes containing a balancing iten have been framed with bold lines.

As is well-known, a matrix presentation permits each transaction to be represented by a single entry and the nature of the transaction to be inferred from its position. Each account is represented by a row and colunn pair and the convention is followed that incomings are shown in the rows and outgoings are stown in the columens. For instance, Gross Domestic Product ( 49 trillion Rupiah) is payable by the economy's producers and received by employed persons and other primary input categories. Table 1 shows this in cell (3,2), that is, in row 3 and colum 2. Since this table distinguishes transactions with the rest of the world in a separate account, the diagonal cells ( $4 \times 566,46566$ ) and $(7,7)$ only contain transactions among national institutional units. The meaning of all individual transaction categories and balancing items in this table will be set out in section 3 below.

The row and colum totals have not been named. Their main function in matrix accounting is to ensure that all accounts indeed represent complete balances, in the sense that total incomings (row sums) equal total outgoings (column suns). In turn, meaningful balancing items, which connect successive accounts, can only be derived if this condition is fulfilled. In general, a balancing item appears in the column of an account and is computed as the row total minus the sum of the other items in the column.

Each entry in an aggregate matrix like table 1 can be considered as the grand total of a submatrix in which the categories of transactors involved at either end of the transactions under consideration are presented. A very useful option in a matrix presentation of accounts is that different types of transactors and groupings thereof can be selected in each account, without giving up the coherence and the integrated presentation of a complete accounting system. In principle, each account can be broken down in two rather different ways:

[^35](1) by subdividing the total economy into groups of units;
and
(2) by assigning the categories of transactions shown in an account to various sub-accounts.

It is discussed next how these two options are applied when developing the aggregate table 1 into a more articulated matrix presentation of the national flow accounts, that is, including both a Supply and Use Table and institutional sector accounts.

First, a subdivision of the total economy in each of the accounts could run as follows:
(1) Distinguish products in the Goods and Services Account and classify these by product groups.
(2) Distinguish establishments in the Production Account and classify these by industries.
(3) Distinguish primary inputs in the Generation of Incone Account and classify these by subgroups of employed persons and of productive assets (jointly called: primary input categories).
(4) Distinguish institutional units in the Distribution and Use of Income Account and classify these by institutional sectors, including a breakdown by subsector for nonfinancial corporations, general government and households.
(5) Distinguish institutional units in the Capital Account and classify these by institutional sectors, including a breakdown by subsector for non-financial corporations, financial corporations and households.
and
(6) If desired, introduce a geographical breakdown in the Rest of the World Account.

These subdivisions have two major consequences. First, for all categories of transactions distinguished in a single cell of table it becomes clear which group of paying units has exchanged what with which group of receiving units. Secondly, the interrelations among various economic flows are revealed through detailed cross-classifications: mappings of one classification to another. For instance, in the example given above, the simple circular flow of income depicted in figure 1 above is then presented, at a meso-level, through the following mappings:
(1) Submatrix (2,1) shows the value of production by industries for each product group.
(2) Submatrix (3,2) shows the generation of income by primary input categories in each industry.

Submatrix ( 46586,3 ) shows the distribution of income to institutional sectors for each category of primary inputs.
(4) Submatrix ( $1,4 \& 5 \& 6$ ) shows the final consumption expenditure of groups of products in each institutional sector.

In this enumeration, the submatrices are identified by means of their location (row and column number, respectively) in table 1. The above sequence represents a closed loop because all account numbers appear in more than one cell and just as frequently in the rows as in the columns. This demonstrates the circularity of the flows described.

The second option for expanding table 1 refers to a distinction of subaccounts. For example, table 2 presents an aggregated 1980 SAM for Indonesia, whereby the Distribution and Use of Income Account is broken down in three subaccounts: an Allocation of Primary Income Account, a
Cial accounting matrix for Indonesia, 1980 (billions of Rupiah)


Secondary Distribution of Income Account and a Use of Income Account. ${ }^{7}$ This means, for instance, that the diagonal item ( $4 \& 5 \& 6,4 \& 5 \& 6$ ) in table 1 is split into property income flows on the one hand (cell 4,4), and current taxes on income, wealth, etc. plus all current transfers on the other (cell 5,5). The sum of the values in these two cells of table 2 is indeed equal to 12.9 trillion Rp., the corresponding figure on the diagonal of the previous table.

Analogously, property income from and to the rest of the world is now separated from current taxes on income, wealth, etc. and current transfers from and to the rest of the world. Finally, the original balancing item in column 3 is split into two parts, the consumption of fixed capital, which is placed on the Use of Income Account, and a new residual, Net Generated Income, which is put on the subsequent account, namely the one describing the allocation of primary income.

Another consequence of introducing subaccounts is that new balancing items, Net National Income (NNI) and Net National Disposable Income (NNDI) appear as closures of the first two subaccounts (allocation of primary income and secondary distribution of income, respectively). The balancing item of the last subaccount (use of income) is typically the same as the balancing item of the aggregate account; here this refers to Gross Saving.

It goes without saying that accounts need not always be broken down but that a further consolidation is also possible. For instance, in table 1 the Generation of Income Account could have been combined with the Distribution and Use of Income Account. As a result, the balancing item Gross Domestic Product (GDP) would have disappeared.

The processes of subdivision (or aggregation) of categories of units and (de)consolidation of accounts are closely linked. In practice, a

[^36]subaccount for one or a few transaction categories is inserted either because a separate classification is required for these categories, or because groups of receiving and paying units should be presented separately for the transactions in these categories. Naturally, an important criterion for maintaining or introducing a separate account is also that it yields a relevant balancing item.

When compiling such a matrix, it is convenient to start with the design of an accounting structure which is relevant to the applications envisaged. ${ }^{\text {s }}$ Subsequently, in each account the most appropriate units and classifications of units are selected. However, in practice it will be an interactive process. Suppose, for instance, that there is a transaction category for which only total receipts and payments of transactors (the row and column totals of a submatrix) are known, and not who paid whom (the interior structure of the submatrix). This problem can be solved by the insertion of an undivided, dummy account. In the Indonesian SAM, the financial account performs this function. This will be elaborated in the next section (see also the Revised SNA's SAM-chapter, para.s 21-22 and Table XX.3).

The possibility to distinguish dummy accounts entails that there is no need to consolidate the matrix to a very aggregated level if for some transaction categories detailed information is not available. Conversely, if on some transaction category abundant information is available and considered relevant for the purposes of the matrix, then a separate account for this category can also be introduced, showing not less but more details. Finally, if, for instance, the Capital Account can only be compiled for two major sectors, this does not imply that the other accounts must also be limited to that number. Summarizing: the matrix format is particularly advantageous if it is not possible or desirable to show an equally detailed classification in all accounts.

At this stage, some general properties of a matrix presentation of accounts can be listed:
8. It is referred to Keuning and de Ruijter [1988) for more extensive guidelines to the construction of a SAM.
(1) An aggregate matrix (like table 2) presents a bird's eye view of an economy as a whole; i.e. one page is sufficient to show the interrelations between main transaction categories leading to a set of domestic and national balancing items.

A detailed matrix presentation is very general: only a matrix presentation allows for a selection of the most relevant unit and classification of units in each account. In other words, both multiple actoring and multiple sectoring can be applied in a matrix. This enables the integration of a detailed supply and use table and institutional sector accounts in a single format for presentation. In turn, this improves the transparency of the complete set of national accounts.
(3) A detailed matrix presentation is suitable for mathematical treatment using matrix algebra; this feature is also quite expedient in the compilation and balancing of national accounts.
(4) A detailed matrix presents a simultaneous breakdown of interrelated transactions by paying and receiving units; as a consequence, it is an appropriate format to reveal, at a meso-level, interrelations among economic flows; this includes those flows which involve two different types of units (e.g., final consumption expenditure of various product groups by a number of household subsectors).
(5) An accounting matrix must always describe a complete economy, however small or large it may be. This implies that a matrix is not the most appropriate format for presenting transactions for an isolated institutional sector, that is, without distinguishing an outside world. The same applies if one wants to obtain time-series for one or a few (aggregate) variables without being interested in their inter-relations at a meso-level.

> If one wants to present all flow accounts as well as balance sheets by institutional sector, a matrix is more cumbersome to read than e.g. T-accounts.

For a set of accounts giving a breakdown of transactions by paying and receiving units, a matrix presentation is more concise than other methods of presentation; the payment of one unit and the receipt of another unit involved in each transaction are represented by a single entry.
and
(8) A detailed matrix is quite suited to experiments with alternative representations of transactions in accounts; in principle, transactions can be paid from one account and received by any other without upsetting the transparency of the system. It must be realized, however, that this reshuffle generally leads to differently defined balancing items.

After this introduction to the general principles of matrix accounting it is perhaps useful to demonstrate how these are applied in the case of the Indonesian SAMs. ${ }^{9}$

## 3. An Aggregate Social Accounting Matrix for Indonesia

Table 2 above exemplifies the design of a SAM which records all transactions distinguished in the national accounts (that is, all flows excluding 'other changes in assets'). ${ }^{10}$ This framework resulted from a

[^37]trade-off between analytic usefulness and the available data. The concepts applied are generally the same as those in the central framework of the revised SNA. The most important deviation refers to a different meaning which is attached to the Generation of Income Account, in order to facilitate a linkage of detailed labour market analyses and the national accounts. This and some other novelties are elaborated below.

This table reflects an extension and a slight re-arrangement of table 1. Apart from the subdivision of the Distribution and Use of Income Account discussed above, the differences are: a Fixed Capital Formation Account and a Financial Balance Account have been added (accounts 8 and 9, respectively), while for the rest of the world separate current and capital accounts have been distinguished (cf. accounts 10 and 11). The addition of one or more accounts entails that some flows are recorded on another account. Possible types of classifications in each account are indicated in parentheses in the row and column headings.

### 3.1 Supply and Use Table as a SAM building-block

The first two rows and columns of table 2 contain an aggregated Supply and Use Table, here explicitly linked up with the other national accounts. ${ }^{11}$

Column 1 presents the supply of goods and services. Although trade and transport margins do not need to be added to output at an aggregate level, they are registered in the top left-hand corner of this table because they are non-zero in a more detailed SAM (e.g., table 3 below), and because the structure of the aggregate matrix and the more detailed tables should be the same, to facilitate cross-references. Output (79048 bill.Rp.) is shown in row 2 and valued at factor cost. This means that all taxes on production less subsidies (298) are not included in the output value, but directly booked on the Allocation of Primary Income

Account for the government (row 4). ${ }^{12}$ Note that the total value of these 'indirect' taxes is very small (only $0.6 \%$ of GDP at market prices!). Below we will see that this is mainly caused by substantial subsidies on some products. Imports, c.i.f. (9886) originate from the current account for the rest of the world (row 10).

The elements in column 1 add up to total supply of goods and services, at purchasers' prices (89231). Row 1 shows the uses of goods and services, at purchasers' prices (also totalling 89231, of course): intermediate consumption (29967) in column 2, final consumption expenditure (31210) in column 6, changes in stocks (1419) in coluna 7, gross fixed capital formation (10476) in column 8 and exports, f.o.b. (16161) in column 10. It can be computed that roughly $20 \%$ of the output value was exported. Notice that Indonesia had a very favourable balance of trade in 1980 (16161-9886-6275 bill.Rp., or +138 of GDP!).

Row 2 shows output, at factor cost. Because of this valuation, the sum of row 2 (79048), and the concomitant sum of colum 2, are exclusive of all taxes minus subsidies on production. In turn, this means that this amount is not included in value added either, see cell (3,2). As a consequence, total value added or GDP (49081) is also valued at factor cost.

### 3.2 Focus on income generation

The third account records the generation of income and plays an important role. It introduces an intermediate unit in between the establishment unit, see account 2 , and the institutional unit, see account 4. In particular, this refers to employed persons, which are considered as the units who receive compensation of employees in the Generation of Income Account and distribute this income to their household in the Allocation of Primary Income Account. These units are subsequently classified into groups of (self-)employed persons (see
12. Ideally, only taxes minus subsidies on products should have been recorded here, in order to value output, Domestic Product, etc. at basic prices (cf. Keunins [1991b] and United fations (1992: section XX.D]). However, in this case it was not possible to separate these levies from the other taxes minus subsidies on production.
section 4 below) and these groups are then a subset of the primary input categories distinguished in this account. This representation serves to integrate labour market analyses and the national accounts.

The central framework of the SNA does not distinguish the employed person as a separate entity (i.e. as a separate unit). This implies that compensation of employees is directly paid from the employer to the household. This treatment overlooks the fact that in many households more than one individual earns an income. The SAM-approach entails that more detailed information is provided on the sources of income of each household group and therefore it throws more light on the linkages between production and income distribution. In addition, this approach allows for a connection of the national accounts to detailed data on employment and to an aggregate (un)employment indicator. This is elaborated in section 6 below.

In fact, separating employed persons from the households to which they belong is an operation which does not fundamentally differ from separating establishments from the institutional units (enterprises) to which they belong. In both cases, the smaller unit is more homogeneous and also fairly autonomous with respect to the economic process in which it is involved (income generation and production, respectively). These units thus serve to obtain a more accurate description of a specific economic process. It may be noted that an employed person as a unit can receive a compensation from more than one job (refer also to chapter XVII, Population and Employment, of the revised SNA).

A definition and classification of the other primary input units, namely productive assets, meets with considerable practical problems. Even in theory, the factors which generate value added are often not carefully identified. For instance, it occurs that output or value added of an industry is assumed to depend on the 'volume' of fixed capital stock in use with the large corporations. There are several flaws in this line of reasoning. First, in many industries a substantial part of operating surplus is earned not by corporations but by the selfemployed. This income should partly, but certainly not wholly be seen as a remuneration for labour input (see e.g Keuning [1985]). The revised

SNA recognizes this essential difference and sets apart the operating surplus of unincorporated enterprises that involves some labour input. This is then called 'mixed income'. In our SAM, we go one step further and explicitly split mixed income into an imputed remuneration for actual labour inputs and a residual generated by asset inputs (see section 5 below).

Secondly, it is not the capital stock used in an industry that should be considered as an input but the capital stock owned by that industry. All rental of capital goods is to be registered as an intermediate input of business services. Like all other intermediate inputs this service is 'used up' in the current production process. A distinguishing characteristic of renting capital goods is its inherent flexibility. The asset in question may be hired intermittently, that is only when the need arises, and even if it is rented on more or less permanent basis, the lessee can cancel this arrangement at any time. ${ }^{13}$ Summarizing, rented capital goods are an input in the production of the lessor and not in that of the lessee.

Thirdly, it is not the stock of fixed capital that serves as an input, but the flow of services derived from this stock. In view of substantial differences in the length-of-life of various produced fixed assets, this implies that long-lived capital goods like buildings, etc. often obtain too high a weight in the capital aggregation function. In our SAM, we use the constant price value of the flow of services, that is, the stock of a certain item divided by its expected length-oflife. ${ }^{14}$ These services are then seen as delivered by one or more categories of fixed assets as subset of the primary inputs. For some purposes, however, it is actually preferable to recognize that the function of the services from fixed capital stock is very similar to that of intermediate inputs and to record them accordingly (cf. Keuning [1992b]).

[^38]Fourthly, the services of non-produced assets contribute substantially to output and value added in most firms. Non-produced assets consist of 1) land, 2) subsoil assets and other natural resources, 3) all kinds of financial assets and 4) various non-financial intangible assets such as patents, copyright, goodwill, trademark, company organization and culture, monopoly power, legal and administrative environment, a network of relations, etc. It goes without saying that particularly the last-mentioned category is hardly identifiable; in some cases, its value or even its 'volume' can perhaps be approximated by means of qualitative criteria.

Concerning financial assets, their input volume is roughly equal to the services derived from a) one year's use of the market value of the stock of all non-financial productive assets owned by the enterprise plus b) the annual costs of all other inputs including own-account labour and fixed capital consumption. In theory, the data for part a) should be obtained from balance sheets by industry while those for part b) are available from the column of the production account in the SAM. Evidently, not all financial assets fetch the same 'price', so that various types of financial asset units must be distinguished. ${ }^{15}$ The classification of primary input units is elaborated in section 4.

If one wants to record domestic net value added as a balancing item in cell (3,2), the primary input categories must encompass all persons employed in resident enterprises. In column 3, compensation of nonresident persons employed in resident enterprises is then handed over to the rest of the world (cell 10,3 ). This implies that a meaningful, national balancing item is only obtained in account 3 if compensation of resident persons employed in non-resident enterprises is added first. This is done in row 3 (cell 3,10).

Analogous to compensation of employees from abroad, other value added received from and paid to abroad should be registered in this table, in cell $(3,10)$ and cell $(10,3)$ respectively. For example: mixed income of a

[^39]resident market-vendor in a neighbouring country where he sets up his stall one day a week. Notice, however, that cell $(3,10)$ only contains value added generated abroad by resident institutional units. According to the revised SNA, this implies that value added created in any substantial amount of production in another country over long, or indefinite, periods of time is excluded; that should have led to the creation of a (quasi-corporate) unit in that country. An alternative approach would be to change the border-line between resident and nonresident units a bit, so that, for instance, direct investment income from abroad is registered in the Generation of Incone Account, while other investment income from abroad is booked in the Allocation of Primary Income Account. ${ }^{16}$

As the consumption of fixed capital is to be considered as a cost item, that is, not as income, it is directly booked on the Use of Income account (\#6) in our SAM. The result of all this is that the Generation of Income Account is closed with a new balancing item (46125), in between GDP and NNI. This balancing item, named Net National Generated Income (NNGI), at factor cost, gives total value added earned by resident institutional units. ${ }^{17}$

### 3.3 Distribution and Use of Income Accounts

The Allocation of Primary Income Account of a detailed SAM presents household labour income(s) as a contribution by one or more (self-) employed household members. In addition, value added from the input of asset services that accrues directly to households is shown separately. Among other things, this indicates to what extent each household group
16. In fact, this elternative booking is based on the assumption that subsidiaries abroad are rather dependent on the parent company. This view is consistent with a convention to record all profits of subsidiaries, that is, includins reteined earnings, as income accruing to the parent company. On the other hand. if an eccountins system creetes an independent unit for a subsidiary abroad, it stands to reason that only actually distributed profita are transforred to the parent company. In this respect, the revised SKA seems not fully conaistent by creatins separate units for subsidiaries abroad and yot treating all their profita as income of the parent company.
17. If one viow the mount of indirect taxes as additional income senerated in production, they should be recorded in cell (3,1) instead of (4,1). In that case. NNGI is automatically valued at markot prices.
depends on multiple sources of income from production. This linkage between incomes of household subsectors and their supply of various types of labour and productive assets is one of the distinguishing features of a SAM. Apart from this, the transaction categories shown in the Distribution and Use of Income Accounts of a SAM are typically about the same as in the central framework of the SNA.

In the row of the Allocation of Primary Income Account (account 4), net generated income is augmented with taxes less subsidies on production, and with property income from the rest of the world (75). ${ }^{18}$ The latter item is recorded in cell ( 4,10 ), which also includes taxes on production and imports less subsidies collected abroad and then handed over to the national government. National, intersectoral property income flows (2671) are recorded on the diagonal (row 4 and column 4), for they change only the distribution, not the total of national income. To get NNI, this diagonal item, as well as property income and such paid to the rest of the world (2999), must be subtracted from the total of column 4, which is derived from the identical total of row 4.

NNI, at market prices (43499) appears on the credit side of the Secondary Distribution of Income Account (account 5). Current taxes on income, wealth, etc. and all current transfers from abroad (30) are also shown here. National, intersectoral current taxes on income, wealth, etc., social contributions and benefits and other current transfers (10202) are recorded on the diagonal (row 5 and column 5). Current transfers and the like to the rest of the world ( 0 ) are recorded on the debit side as is the balancing item, Net National Disposable Income (43529), which is put on the Use of Income Account.

In table 2, the Use of Income Account (account 6) records spending of gross disposable income: final consumption expenditure on goods and services and Gross Saving (15275), which is put on the Capital Account. The gross saving rate in Indonesia in 1980 was estimated at 33\%.).

[^40]
### 3.4 Capital, Fixed Capital Formation and Financial Balance Accounts

In the design of a SAM, it might be considered to include a Capital Account that is classified by institutional sector and a Financial Account that is classified by type of financial asset. As a consequence, a disaggregation of such a SAM would show, by institutional subsector, both acquisitions less disposals of various financial assets and incurrence less repayment of various liabilities. In the SAMs presented here, not enough information on these flows was available, particularly for 1975 . $^{19}$ This implied that only the financial balance is shown by institutional sector and for the rest of the world.

Row 7 presents gross saving, capital transfers receivable from the rest of the world (1219) and the diagonal item, national intersectoral capital transfers receivable (1236). ${ }^{20}$ Column 7 records how these funds have been allocated: changes in stocks, national intersectoral capital transfers payable, gross fixed capital formation (10476) and capital transfers payable to the rest of the world ( 0 ). The balancing iten is Net Lending of the Nation (4600). Interestingly, this balance is quite positive and even much larger than the development assistance received by Indonesia in 1980 (see cell 7,11).

The main part of total volume changes in net worth probably consists of increases in fixed assets. If one is particularly interested in the dynamics of an economy, it is important to show in which industries production capacity has been expanded. This is the aim of the Fixed Capital Formation Account (account 8) inserted in this SAM. A more detailed table, such as table 3 below, then presents:
(1) who invests where in the rows of this account - cell (8,7);
and

[^41](2) where does one invest in what in the columns - cell (1,8).

In this case, the who refers to an institutional subsector, the where refers to an industry, and the what refers to a product group. Note that through this Fixed Capital Formation Account the SAM shows at a mesolevel the linkages which exist between fixed capital formation by institutional sector, as presented in the Capital Account, and fixed capital formation by category of goods and services, as contained in the Supply and Use Table. In other words, a second economic cycle, shown at the right-hand side of Figure 1 above, is now closed as well.

The Financial Balance Account (\#9) records the financial balances of institutional subsectors (cell 9,7 ) and of the rest of the world (cell 11,7). Naturally, Net Lending of the Rest of the World (-4600) is the mirror image of the nation's financial balance, so that this account always adds up to zero. For that reason, the column of this account is empty and has been deleted.

### 3.5 External transactions accounts

The elements in the current and capital account for the rest of the world (accounts 10 and 11) have all been discussed above, except the Current External Deficit (-3381) shown in row 11 and column 10. It is obvious that the oil boom has led to a sizeable surplus for Indonesia in 1980. If one wants to consider this balance from the perspective of the national economy, it should be put in row 10 and column 11 and the sign reversed.
4. Classifications in a More Detailed SAM

### 4.1 Some considerations regarding the definition of classifications

It stands to reason that SAMs for different countries select a common type of classification in each account, but that the actual (detailed) classifications are based on local conditions. Defining these taxonomies
is a vital phase in the construction of a SAM, as its uses depend very much on the categories distinguished.

When it comes to the design of classifications, a broad distinction could be made between two types of SAMs:
(1) SAMs principally used for monitoring;
and
(2) SAMs principally used for analysis.

The taxonomies in the first type of SAMs should be determined by what one wants to monitor, or by the taxonomies in the object of comparison (e.g., a SAM for an earlier period or another economy). For the rest, not many general remarks can be made. The remaining part of this section will thus focus on classifications in a more 'analytical' SAM.

As transactions in a SAM are shown simultaneously as a receipt of one (sub)account and an outlay of another, they are usually crossclassified. The usefulness and feasibility of such cross-classifications should thus be considered when designing the taxonomies for each account. In an 'analytical' SAM this implies that a well-balanced number of categories must be distinguished in each ('endogenous') account. For example, in an analysis of the circular flow of income on the basis of 200 products, 50 industries, 2 labour categories and 3 household groups, a bottleneck will appear in between the primary income and final expenditure flows. In other words, such an analysis requires that the number of labour and household categories is about the same as the number of products and industries.

The following considerations may serve to guide in defining a classification:
(1) The homogeneity of the categories distinguished, regarding the transactions recorded in the account under consideration; ideally, all units in a single category
operate on the same markets, both on the supply (input) and on the use (output) side of the economic process concerned.
(2) The recognizability of the subgroups and their relevance to economic analyses and to policy preparation and monitoring (including e.g., key industries, regional aspects and identifiable target groups).
(3) The stability and measurableness of the characteristic(s) on which the classification is based, and the fewness of survey questions which are needed to establish the classification.
and
(4) The degree to which the (cross-)classification(s) can be derived from (a combination of) existing data sources.

The classification of households is particularly crucial. Conclusions regarding (changes in) inequality, and perhaps even poverty, may have to be based on subgroup averages, and thus depend very much on how the population has been subdivided. On the one hand, any feasible number of household groups may lead to categories containing over a million people, say, and this must imply that average figures conceal considerable within-group disparities. On the other hand, integrating distributional statistics into a SAM considerably increases their reliability as well as their relevance. Summarizing, this heterogeneity should not be a problem if a proper classification is selected, that is, if the shapes of the underlying within-subgroup distributions are fairly similar, or if the spread mainly concerns incidental or less relevant differences (e.g., life-cycle effects).

In the light of these considerations, main income source seems more adequate criterion than income size when it comes to classifying households. This principle has also been applied in the design of the standard SNA-subsectors: employers, own-account workers, employees and recipients of transfer or property income [United Nations, 1992: section
IV.G.3]. These categories may however still be too heterogeneous, so that additional breakdowns are needed. In this regard, location (urban/rural or distinguishing several regions), possession of assets (e.g., agricultural land) and size and composition (with/without children) of the household appear to be relevant criteria. A further breakdown could then be based on main economic activity of the household and main subsector of employment, occupation, educational attainment, etc. of the reference person.

Even in a 'monitoring' SAM, classifying households by incone size or expenditure bracket may be problematic, since income and expenditure are neither easily measurable nor stable while they require a lot of survey questions - so that the information contained in e.g., household and population surveys which do not ask these questions cannot be linked up with such a SAM.

The classification of households need not be the same in each type of account. For instance, a breakdown of the category of economically inactive households may be more useful in the Secondary Distribution of Income Account than in the Allocation of Primary Income Account.

The classifications of other institutional units typically resemble those in the central framework of the revised SNA. In addition, some or all accounts for the rest of the world may be geographically subdivided, especially if the SAM-economy (country or region) belongs to a larger commity where special (trade) regulations apply, or if its functioning is closely linked to a particular part of the outside world (e.g., through a tied currency).

If the SAM is to serve as a bridge between conventional national accounts information and an employment indicator (see section 6 below), the classification of employed persons has to fulfil two minimum requirements:
(1) employees and self-employed persons must be separated;
and
(2) resident persons employed in non-resident enterprises and nonresident persons employed in resident enterprises must be singled out.

For the rest, the classification of (self-)employed persons may be based on a combination of background and (main) job characteristics, like sex, schooling, age, ethnicity and place of residence on the one hand, and occupation, type of job contract (full-time/part-tire, permanent/ temporary), region and subsector of employment on the other hand. Another consideration should be that within-group variations in relative wage rate changes are smaller than between-group variations. In common with the household taxonomy, an inverted tree-structure may be built. A classification by industry of employment is less relevant, because this is already shown in the SAM by the cross-classification of value added. If, for example, employees in establishments belonging to a corporate enterprise are separated from those working in unincorporated firms, and the industries are tabulated by ISIC-class, the primary input submatrix would show labour income in plantations separately from labour income in small-holdings growing fruit, nuts, beverage or spice crops.

In practice, non-produced asset units can only be distinguished in the SAM-framework if such a (volume) unit is in fact observable, that is, if price and volume changes can be disentangled. In addition, sufficient data on the own-account input of this asset should be available and as well a reasonable imputation for the price (changes) thereof. For instance, if a well-developed market exists for the rental of farm-land of various qualities and if the (own-account) input of these types of land is regularly surveyed, part of agricultural mixed income and operating surplus could in fact be assigned to the services derived from using land. A similar procedure may be followed for some subsoil assets, for $R \& D$ assets like patents, etc.

In this way, several categories of property income payable, including an imputation for self-earned property incomes, would be distinguished as sub-components of mixed income and operating surplus by industry. This serves to yield more insights into (1) which (primary) inputs have produced the outputs of a certain industry and (2) which subsectors have
provided these inputs. For the time being, a complete enumeration is not feasible; a remuneration for the use of some assets, like the organization of production or the external environment, cannot usually be isolated. The 'unexplained' value added may then be classified by subsector to which the establishments in each industry belong. The rationale for this is that the relative use of these unidentifiable inputs may be more homogeneous by subsector than by any other operational classification criterion. Notice that this principle implies that (part of) operating surplus is cross-classified by industries and institutional (sub)sectors in the SAM (cf. table XV. 7 in the revised SNA's chapter on Supply and Use Tables and Input-Output).

Products may be distinguished by type, adapting the Central Product Classification (CPC) [United Nations, 1991] to specific circumstances and needs, followed by a subdivision of some of these categories into domestic products and imports. Sometimes, products which are apparently very much alike ought not to be grouped in a single category because they are traded in totally different markets, at very different prices. As a rule, an important consideration in a taxonomy of products should be that within-group variations in relative price changes are smaller than between-group variations.

For industries, it is sometimes useful to supplement a local variation of the ISIC by a classification by institutional subsector of the enterprise to which the establishment belongs; there may be informal household firms and foreign-controlled corporations which produce similar products, like clothing, but these establishments do not operate on the same output or input markets. In addition, key industries could be set apart. In the Fixed Capital Formation Account, a different (more aggregated) taxonomy of industries can be applied.

### 4.2 Classifications in the Indonesian SAMs

Obviously, in practice only a few classification criteria can be applied simultaneously. It is therefore expedient to start from an inverted
tree-structure. Figure 2 exemplifies this process of successive
subdivisions in the case of the household taxonomy in the Indonesian SAMs. ${ }^{21}$ This classification was designed by Downey [1984, 1985], following the provisional guidelines as published by the United Nations [1977]:
(1) all non-institutional households are split into agricultural, rural non-agricultural and urban nonagricultural;
(2) agricultural households are split into agricultural employees and farmers (own-account workers and employers combined);
(3) rural and urban non-agricultural households are split into i) 'lower' level (defined in step (7) below), ii) economically inactive (that is, recipients of transfer or property income) and iii) 'higher' level (defined in step (9) below):
(4) agricultural labourers are not further broken down;
(5) farmers are split into small farmers, medium farmers and large farmers, depending on the size of land owned;
(6) small, medium and large farmers are further partitioned, in six, two and five subgroups, respectively, depending on the size of land owned (see figure 2);
(7) 'lower' level rural and urban non-agricultural households are split into three subgroups: i) own-account workers, excluding professionals and technicians and own-account workers in 'modern' service industries (ISIC: 61,64,81-83), ii) 'lower' level clerical, sales and service employees
21. Originally, the claseifications in the 1975 and 1980 SAMs were not exactly the asme. The most aerioue deviations heve been repaired (see Keuning [1993: forthcoming]) while the reanining, aceall differences typically occur at the mot detailed lovel of the claseification which have not been used in the final reconciliation of both SAMs.

## 



(1.-x.) 1.- 40. All Non-institutional households


Rural Non-agricultural


(ISCO $36,37,45,49,52-56,58,59$ ) and iii) manual employees; ${ }^{22}$
(8) economically inactive rural and urban non-agricultural households are subdivided in accordance with the age of the head of the household: i) <25 years, ii) 26-50 years and iii) $>50$ years; in addition, these households include the (insignificant) subgroup of unclassified households;
and
(9) 'higher' level rural and urban non-agricultural households are split into i) employers, ii) own-account professionals and technicians and own-account workers in 'modern' service industries (ISIC, Rev.2: 61,64,81-83), iii) managing and supervising employees, iv) professional and technical employees, v) 'higher' level clerical, sales and service employees (ISCO $32-35,38,39,42-44,57$ ) and vi) military employees.

All in all, this yields 40 subgroups ( 14 agricultural, 13 rural nonagricultural and 13 urban non-agricultural). When constructing the SAMs, this classification has mostly been used. However, the final reconciliation of blocks of the SAM has been done at a higher level of aggregation. This agrees with the 10 groups indicated with Roman numerals in figure 2.

In addition to the household subgroups, only two sectors have been distinguished in the Indonesian SAMs: corporations and the government. A breakdown of the corporate sector will not be shown in this paper, although it was used when compiling some parts of the SAMs (this concerns: private national, public oil and non-oil, foreign oil and nonoil corporations, respectively). Besides, some computations have been carried out for four levels of government: central, provincial, district and municipality level.
22. ISIC stands for International Standard Industrial Classification of all economic activities, Revision 2 [United Nations, 1968b] and ISCO means International Standard Classification of Occupations [International Labour Office, 1957]. In both cases, an updated version has appeared after the completion of the (re-)tabulations of basic data which underly the Indonesian SAMs.

Data limitations necessitated that only two sectors are distinguished in the Capital Account, namely a private sector (households and corporations) and a public sector (government). However, in our matrix format such data limitations in the field of capital expenditures do not have any repercussions on the classification that is applied in the current accounts. Here we see one of the advantages of the multiple sectoring property of accounting matrices.

The most extensive classification of labour in the Indonesian SAMs encompasses 40 categories: rural/urban $x$ paid/unpaid $x$ male/female $x$ five occupations (i) agricultural worker, ii) manual worker, iii) clerical, sales or service worker, iv) professional or technician and v) manager or supervisor). Obviously, paid labourers are employees, while unpaid labourers consist of employers, own-account workers and unpaid fanily members. As comuting from and to a neighbouring country is negligible in the case of Indonesia (cf. cells ( 3,10 ) and ( 10,3 ) in table 2), there was no need to distinguish separate categories for resident persons employed in non-resident enterprises and non-resident persons employed in resident enterprises. In the most detailed tables that will be presented in this paper, a somewhat less detailed classification is mostly applied: 16 categories, whereby the last dichotomy of the above list is dropped and occupational categories iv) and v) are combined.

Asset income has first been subdivided into produced capital income and non-produced capital income. The former equals the consumption of fixed capital. Subsequently, the latter is classified by institutional sector of ownership: i) unincorporated, ii) corporate private national, iii) public, and iv) foreign. In principle, the income accruing to joint ventures has been split in accordance with the shares held by both parties. Next, unincorporated net operating surplus has been singled out. This only refers to net income from owner-occupied housing and has therefore been labelled: unincorporated net housing income. The part of mixed income that is generated by non-produced capital input is then subdivided by type of activity in which it is generated: agricultural versus non-agricultural. Obviously agricultural land input is an important determinant of the former category, but it also includes e.g.
a remuneration for the use of financial capital in agriculture. Finally, non-housing unincorporated non-produced capital income generated outside agriculture is subdivided by two household subsectors of ownership: rural versus urban households. All in all, this yields eight categories of non-labour primary inputs. ${ }^{23}$

As an Input-Output Table instead of Supply and Use Tables was used in the construction of the Indonesian SAMs, the classification of products and industries is essentially the same. In the most detailed SAMs, this classification is a somewhat aggregated version of the two-digit ISICtaxonomy (Rev.2). A conversion of the 1975 and 1980 Input-output classifications into ISIC and SAM-classification is presented in the Appendix to Keuning [1993, forthcoming]. Apart from this, all products have been distinguished into domestically made and imported. This is thus also shown in the Use Table, by intermediate and final demand categories and by product group. In addition, tables on household consumption have been compiled for a more detailed taxonomy of products which results from a combination of the categories distinguished in the most detailed Input-Output table and the household budget survey (see Downey [1988] and Sutomo [1989]).

## 5. More detailed SAMs for Indonesia

5.1 A somewhat elaborated SAM

The aggregate SAM for Indonesia (table 2) serves as a reference table for subsequent, more detailed tables. The 1968 SNA expressed this procedure as follows: "By following a concise, economical notation, a good notation as mathematicians would say, we can see the wood and at the same time retain the trees." [United Nations, 1968a: paragraph 1.24]. In the more extensive presentation of the Indonesian economy (supply and use table, sector accounts etc.), the linkage between the detailed submatrices and the aggregate SAM is established through a

[^42]system of codes.

An intermediate stage towards a full-fledged SAM is represented in table 3. This matrix mainly serves a didactic purpose. On the one hand, it represents about the largest SAM that can still be printed on a single page, which may facilitate its reading by an outsider. On the other hand, almost all accounts are sufficiently broken down to demonstrate some of the distinguishing features of such a SAM-framework. Among other things, it shows:

- The circular flow of income, including a subdivision of labour income by eight categories of employed persons; this enables a more detailed analysis of the linkage between value added of industries and primary income of household subgroups.
- The interdependence between the distribution of income and the structure of production; among other things, this is related to diverging demand patterns of various (six) household groups.
- The subsectoral allocation of saving, including a subdivision of fixed capital formation by investing industry; this enables a more detailed analysis of the linkage between fixed capital formation of subsectors and fixed capital formation by category of goods and services.

In this table, the distribution and use of income accounts (nr.s 4, 5 and 6 in table 1) have been combined. If necessary, the previous table might again be consulted for the meaning of each non-empty block.

Rows la-lJ give the upper part of a Use Table. The destination of imported and domestically made products is shown for five product groups. It is obvious that households consume relatively few imported products; cf. the numbers in submatrix (1F-1J, 4_6A-4_6F) and in submatrix ( $1 \mathrm{~A}-1 \mathrm{E}, 4 \_6 \mathrm{~A}-4 \_6 \mathrm{~F}$ ). Mining and manufactured products make up 81\% of the purchasers' value of imported products; cf. the total of rows


1F-1J. Most of these imports are used as intermediate inputs or as fixed capital goods in the domestic mining, manufacturing and construction industry; cf. the figures in row 11 . Notice that only in this industry the acquisition of capital goods of foreign origin surpasses that of domestic manufacture; cf. row vectors (1C, 8) and (1I, 8). More details on demand patterns by household subgroup, inter-industry deliveries, exports and investment by capital good and industry of destination will be discussed elsewhere (Keuning [1993: forthcoming]).

Column 1A-1J have the format of a Supply Table with rows and column transposed. ${ }^{24}$ However, the Make Matrix (2A-2E, $1 A-1 E$ ) is not fully articulated in this case; it is a diagonal matrix as the Indonesian Input-Output Table was converted into the present format. The row vector in the top left-hand corner ( $1 \mathrm{~K}, 1 \mathrm{~A}-1 \mathrm{~J}$ ) contains a specification of the trade and transport margins. It shows the relevant margins on domestic and imported products, and records the sum of these as a negative entry in the column for trade and transport services (cell $1 \mathrm{~K}, 1 \mathrm{D}$ ), such that the figures in this block add up, row-wise, to zero; cf. the total of row 1 K . Consequently, column 1 K is empty and has been deleted. This way of recording ensures that the total of columns 1A-1J (total supply) is valued at purchasers' prices, just like total uses of these product groups; the totals of rows and columns $1 A-1 J$ are thus the same. ${ }^{25}$

The row vector ( $4-6 \mathrm{H}, 1$ ) gives 'indirect' taxes minus subsidies. It is obvious that none of the product groups distinguished in this table is heavily taxed. In fact, imports are even subsidized, on balance. Imports, at c.i.f. prices, are recorded in vector (10, $1 \mathrm{~F}-1 \mathrm{~J}$ ). Notice that the trade balance for food and food products and for services is negative; cf. vectors $(1,10)$ and $(10,1) .{ }^{26}$
24. In wy view, a presentation of the Supply and Use Table like roms and columa 1 and 2 in this table is clearer than ita presentation in the SMA (United Nations, 1992: chapter XV), whereby only the Use fable records resources in the rows and uses in the columas; this is reversed in the SMA's Supply Table.
25. For some purposes, an alternative may of recording trade and transport margina mey be preferable; e.e., recording these margins on all uses separately, that ia, in (1K, 2-10), and allocating them as a production of the trade and transport industry in the column for these margins (cell $2 \mathrm{D}, \mathrm{iK}$ ); the figure in cell (2D, 1 D ) is then reduced by this mount. Bowever, this luplies that uses of other product sroups are no lonser valued at purchasers' prices.
26. The figure in cell (1I, 10) agress mith domestic trade margine on goods in transit; see cell (iK,iI). Thase unspecified products had to be clessified with peraonal and household services.

Rows $2 A-2 E$ record output by industry and columns $2 A-2 E$ contain various kinds of inputs by industry. The intersection between these columns and rows $3 A-3 K$ presents a decomposition of Gross Domestic Product, at factor cost, by primary input category and by industry. In this submatrix, compensation of employees is shown for four occupational categories and separately for paid and unpaid labourers. In the latter case, this obviously concerns an imputed compensation. These imputations have been calculated at a very disaggregated level (1368 labour categories), based on hours worked of the self-employed and the average wage rate of employees with the same background and job characteristics. It is clear that for agricultural workers and clerical, sales and service workers the imputed remuneration for the labour of the selfemployed largely surpassed the actually paid wages and salaries, while for manual workers and professionals, technicians, managers and supervisors the reverse applies; cf. the total of rows 3A, 3C, 3E and 3G with that of rows 3B, 3D, $3 F$ and 3 H , respectively. Below, these valies will be decomposed into a volume (full-time equivalent employment) and a price (average wage rates).

The remuneration for the input of assets in production is split into a remuneration for the use of produced fixed assets (row 3 K ), that is, depreciation costs, and a residual, which has been assigned to two categories of owners by production activity: private national and public/foreign proprietors. The latter receive even more net non-labour income than the former; cf. the total of rows 3 I and 3 J . This is largely due to the enormous profits in (oil) mining; see cell (3J,2C) and table 4 below.

Rows $3 A-3 K$ register the receipts of national primary input units. The allocation of primary income to institutional subsectors is presented in columns $3 A-3 K .^{27}$ As all elements of both the vectors $(3,10)$ and $(10,3)$ are zero, domestically generated income equals nationally generated income in this case. The figures in submatrix (4-6, 3) demonstrate that all household subgroups have multiple sources of income generated in

[^43]production. For instance, the households of agricultural labourers acquire only half of their generated income from wages and salaries of agricultural workers. Apart from this subgroup, wages and salaries also account for a large share of generated income in the subgroups of higher level non-agricultural households.

The rows $4-6$ contain not only generated income but also other current receipts of the institutional subsectors: property income, taxes on income, wealth, etc. and current transfers. In the Indonesian SAMs, interest, dividend, rent, etc. are recorded on a net basis, that is, as receipts minus payments. ${ }^{28}$ Dividends and part of the interest flow from corporations, including public corporations, to households and to other corporations. In fact, these receipts mainly accrue to higher level urban households; see vector (4_6A-4_6G, 4_6G). Property income attributed to insurance policy holders was considered negligible.

Current taxes on income, wealth, etc. are recorded in the vector ( $4 \_6 \mathrm{H}, 4 \_6 \mathrm{~A}-4 \_6 \mathrm{G}$ ). It is obvious that the lion's share of these levies is borne by (oil) corporations. This vector also includes a small part of land rent, paid by households to the government. Social assistance benefits are paid by the government and received by households. These grants are not very substantial; cf. vector (4_6A-4_6F, 4_6H). Transfers between different layers of general government are given in cell (4_6H,4_6H).

The rest of the intersectoral current transfers (social contributions, other social benefits that are not in kind, non-life insurance premiums and claims, and other transfers) have been consolidated or considered negligible, in so far as they did not involve a household as one of the transactors. ${ }^{29}$ For the household subsectors,
28. Only part of the interest is recorded here, since indirectiy paid bank services were already allocated to the supposed users in the Indonesien Input-Output tables. In contrast with reelity, only the borrowers of money and not the depositore have been congidered as users of these bank services when compiling the Input-Output tables. This wey of recordins has not becn changed here, in order to maintein consistency between the same and the Input-Output tables, although enother approach is to be preferred (Keuning, 1990).
29. This excludes social transfers in kind such as household benefita of public expenditures on education and health. It is preferable to record such transfera in a supplementary table; refer to section 6 and foot note 35 below.
they have been recorded on a net basis, and directly from the paying subsector to the receiving one. In other words, intermediaries like social security funds, pension funds, insurance corporations, etc. have been skipped, except for their service charges that were recorded as household consumption. There are two reasons for this short-cut. First, data on these transfers were virtually lacking, and secondly, the social security system was still very much in its infancy in Indonesia in the second half of the seventies. ${ }^{30}$ Regarding non-life insurance, it has been assumed that in each household group the claims equalled the premiums minus the service charges accruing to the insurance corporations. In other words, receipts minus payments of these current transfers was nil in all cases. This implies that submatrix (4_6A-4_6F, 4_6A-4_6F) records receipts (row-wise) and payments (column-wise) of social benefits and contributions, pension fund benefits and premiums excluding service charges, and miscellaneous current transfers. The only recipients are the economically inactive households (e.g. students, households headed by a jobless female whose husband lives and earns an income in another location, unemployed and old-aged, in so far as all such household heads live on their own).

Property income and transfer receipts from the rest of the world are registered in vector ( $4 \_6,10$ ). For households, this concerned remittances of emigrant workers. Corporations received interest and dividend from abroad. Finally, the 1980 receipts of unrequited official transfers as recorded in the balance of payments should be partly seen as current transfers according to an official publication on Indonesia's government accounts [Biro Pusat Statistik, 1985]; cf. cell (4-6H,10).

Columns 4-6 record for all institutional subsectors: final consumption expenditures (rows $1 \mathrm{~A}-1 \mathrm{~J}$ ), intersectoral payments of property income and current transfers (rows 4_6A-4_6H), gross saving (rows 7A-7B) and payments of property income and current transfers to abroad (row 10). It is obvious that profit outflows by foreign-owned Indonesian subsidiaries were substantial (cell 10,4_6G). The bulk of cell ( $10,4 \_6 \mathrm{H}$ ) refers to interest payments on government debt.

Data limitations necessitated a more condensed classification of institutional sectors in the capital account (\#7). The mapping from the more elaborate sector classification in the income distribution and use account to the more aggregate taxonomy in the capital account is shown in the submatrix (7A-7B, 4_6A-4_6H). This subasatrix contains the balancing item of the income distribution and use account, whereby gross saving of the first seven subsectors is allocated to their combined capital account. Only government saving is shown in a separate row (cell 7B,4_6H).

For the rest, the rows of the capital account record capital transfers received from other sectors (submatrix 7A-7B, 7A-7B) and from abroad (7A-7B, 11). Transfers from the government to the combined corporations and household sector (cell 7A,7B) mainly concerned investment grants allocated to public enterprises. ${ }^{31}$ Intersectoral acquisition less disposals of non-produced, non-financial assets (land, intangible non-produced assets, etc.) has been considered negligible.

An allocation of these funds is specified in columns 7A-7B. First, changes in stocks are recorded in the submatrix (1A-1J, 7A-7B). Special attention should be paid to sectoral differences in the allocation of gross fixed capital formation to industries (see submatrix 8A-8E, 7A7B). It is obvious that the contribution of the government sector to total investment was quite substantial, particularly in agriculture and (government) services.

The financial balance of the combined corporationsthouseholds sector and the govermment sector is given in the row vector (9, 7A-7B). This balance is positive, even for the government, which is probably due to the particularly favourable economic conditions in this year ('oil boom') .

The elements in rows and columns 8A-11 have already been discussed above.

[^44]A more detailed SAM cannot usually be presented on a single page. Even if this is technically feasible, it would entail that much empty space is shown on one, very large sheet of paper. In turn, that may not lead to an optimal absorption of information by the reader. Instead, the labelling system described above could be used to present one non-empty block (or a few small, adjacent blocks) at the time. This idea is illustrated in the next section.

### 5.2 A detailed value-added submatrix

Table 4 unveils part of the information contained in the full-fledged SAMs for Indonesia. It looks at 1980 GDP, i.e., cell (3,2) of the aggregate table 2, through a magnifying glass. This submatrix is part of the (131xl28) SAM that will be presented in Keuning [1993: forthcoming]. The industry classification is a somewhat aggregated version of the Indonesian variant of two-digit ISIC (Rev.2). Cross-reference with the five production activities distinguished in the previous table is possible through the coding system. Furthermore, each group of employed persons in Table 3 is broken down by their residence; rural or urban. Concerning net non-labour income, receipts from the input of seven categories of non-produced capital have been distinguished here: unincorporated capital in agriculture (e.g. farm land used by smallholders), unincorporated capital in owner-occupied housing (e.g. financial capital), unincorporated capital in other rural production activities and in other urban production activities, corporate private domestic capital, public capital and foreign capital (cf. subsection 4.2 above).

In addition, some interesting subtotals are provided: e.g. male and female labour income, gross mixed income and gross operating surplus. The new SNA utilizes the term mixed income for unincorporated operating surplus, excluding the operating surplus from owner-occupied housing. Note that in this table both labour income and mixed income include 'unpaid' labour income, that is an imputed remuneration for the labour of the self-employed (employers, own-account workers and unpaid family workers). The imputed compensation of a self-employed person unit has

been estimated as hours worked times the hourly wage of an employee with similar background and job characteristics in the same industry.

From this table the following illustrative conclusions can be drawn:

The share of 'pure' capital income, that is, excluding imputed labour income of the self-employed, in GDP was very high: 64t. This was mainly due to the huge windfall profits in (oil) mining, which accounted for about a quarter of GDP. However, unincorporated capital income was certainly not negligible; for instance, in food crops cultivation half of value added accrued to this category and this mainly reflected a remuneration for the input of agricultural land.

- The share of total labour income varied sharply by industry: from 18 in mining to 978 in personal and household services. Even within agriculture and within manufacturing this proportion was far from uniform; e.g. 17\% in forestry vs. 51\% in food crops cultivation and $19 \%$ in chemicals, basic metals and non-metallic minerals manufacturing vs. $60 \%$ in wood and wood products manufacturing and construction.
- Overall, 90\% of capital income concerned a remuneration for the input of non-produced capital; however, in utilities, transport and communication and real estate and business services the costs of the consumption of fixed capital made up more than $20 \%$ of gross value added.
- Female labour income accounted for $20 \%$ of total labour income. This share was particularly low in transport and communication, fishery, and wood and wood products manufacturing and construction. Only in restaurants, textile manufacturing, and trade and transport services women earned more than $30 \%$ of total labour income. Three industries - trade and transport services, government,
social, cultural and recreational services and food crops cultivation - generated 68\% of total female labour income and $54 \%$ of total male labour income.

Labour income was fairly equally spread over the four occupational categories distinguished here, whereby clerical, sales and service workers obtained somewhat more than a quarter (318) and professionals, technicians, managers and supervisors somewhat less (198). Clerical, sales and service workers obtained the highest share in mining and in all service industries, except transport and government, social, cultural and recreational services. The latter industry was the only one were professionals, technicians, managers and supervisors dominated the wage bill. In fact, these workers received almost three quarters of their income in that activity.

58\% of labour income accrued to rural households; apart from agriculture, more than half of labour income also went to rural areas in quarrying, wood and wood products manufacturing and construction and food processing.

Imputed labour income to the self-employed accounted for $45 \%$ of the total; almost two thirds of this income was earned in two industries: trade and transport services and food crops cultivation.

Unincorporated capital income accounted for slightly over one third of total non-labour income; excluding the windfall profits in (oil) mining, this proportion rises to 58\%. Gross mixed income surpassed gross operating surplus in agriculture and food processing, quarrying, textile manufacturing, and the services in group 2D except other transport and communication.

More than half of corporate capital income accrued to foreign share-holders. This was mainly due to their


#### Abstract

dominant role in the very lucrative oil business. However, as these proceeds were subject to a special tax, the proportion of after-tax capital income appropriated by foreign investors was much smaller.


- Many branches of industry were dominated by public enterprise: chemicals, basic metals and non-metallic minerals manufacturing, utilities, other transport and communication and banking and insurance.

The above list illustrates that this part of a full-fledged SAM yields all kinds of insights into the distribution of value added by industry. However, this is not the full story. The essence of the SAM is that table 4 has not been constructed in isolation, but is fully integrated with the Supply and Use Tables (accounts 1 and 2 in the SAM) on the one hand and with disaggregated sectoral accounts (accounts 4-7 in the SAM) on the other. ${ }^{32}$ The detailed information in table 4 can therefore be linked to meso information on other economic processes.

In particular, this enables all kinds of meso-level analyses that focus on the linkages between processes of production and generation of income on the one hand and processes of (re)distribution and use of income on the other hand. An example of such an analysis is provided in Keuning [1992b].

Both labour statistics and the national accounts do not only deal with labour incomes. Perhaps even more important is a decomposition of these values into a volume and a price component by labour type and industry: full-time equivalent employment and (weighted, full-time equivalent) wage rates, respectively. The advantages of linking such detailed volume and price information to the SAM-values are evident. This is but one example of the extensions that are needed to arrive at an optimal meso-level information system for monitoring and analyzing an economy. A more systematic review is provided in the next section.

[^45]6. Towards a System of Economic and Social Accounting Matrices and Extensions (SESAME)

### 6.1 General principles

In many cases, it is expedient to reconcile the SAM-figures and related data which are available from all kinds of dispersed sources. This leads to supplementary tables which show:
(1) Various stocks underlying the SAM-flows, such as size and composition of the population by household group (including the potential labour force), production capacity by industry and the possession of assets (e.g., agricultural land, consumer durables and financial assets) and liabilities (e.g., external debts) by subsector. ${ }^{33}$
(2) A decomposition of (changes in) values into (changes in) volumes and prices; this refers not only to products but also to various categories of labour services, and to fixed capital formation by industry. ${ }^{34}$
(3) Related non-monetary socio-economic indicators, such as life expectancy, infant mortality, adult literacy, nutrient intake, access to (public) health and education facilities, and housing situation by household group; cf. the United Nations [1975] publication on a System of Social and Demographic Statistics (SSDS). In addition, envirommental data and summary indicators should be included.
(4) Some imputations and re-routings; it may not be opportune or feasible to insert in the SAM all imputations and reroutings prescribed by the revised SNA, but in that case

[^46]
#### Abstract

satellite tables can serve to bridge the gap between a SAM and accounts that are supplied to international organizations; this concerns, for example, final consumption by household group paid for by government and private non-profit institutions. ${ }^{55}$


and
(5) A breakdown of several transactions shown in the SAM according to a third criterion. Examples of such threedimensional tables are: (1) property incomes by type (rent, dividend, interest, etc.) as well as by paying and receiving subsector, (2) financial transactions both by type of financial asset and by creditor and debtor sector, and (3) generated income by primary input categories and as well by paying industry and by receiving subsector.

Such an extended set of tables (i.e., a core' SAM and its various satellite tables) may be called: a System of Economic and Social Accounting Matrices and Extensions (SESAME).

Key features of a SESAME are: integration and multiple classifications; in other words, a conceptual and numerical linkage of all kinds of related monetary and non-monetary phenomena, which are expressed in different measurement units. A SESAME registers for all variables both the national total value and its distribution among socio-economic household groups, categories of employed persons, etc. As a next step, a whole range of sumary indicators can be derived from such a data set, including indices that cover distributional aspects (e.g. GDP, NNI, population size, (un)employment, inflation, balance on current account of the balance of payments, income inequality,
35. For monitoring purposes, the tertiary income distribution could also be shown in the SAM proper. However, these imputations ahould be set aside in an analysis that makes uae of average or marginal expenditure propensities. As redistributed income in kind it by definition fully spent on certain goods and services, its size influences neither saving nor the final consumption of other products. Incorporating auch imputations in the SAM proper would thus distort an evaluation of household expenditure decisions. Note, though, that the ame applies to income imputed when valuing output for own final consumption et equivalent market prices (subsistence production, services of owner-occupied dwellings, etc.) and to wages in kind.
environmental indicator(s), daily calorie intake of the poorest subgroup, average number of years of schooling, etc.). Whatever set of aggregates is preferred, they would all share one crucial feature: every indicator is computed from a single, fully consistent statistical system. ${ }^{36}$

A SESAME opens the door to a more general insight into the state of human development without giving up a system's approach. The advantage of such an approach are in terms of increasing relevance, reliability and efficiency. Relevance is increased because the derivation of main economic and social indicators from a single meso-level information system means that linkages among their values can be analyzed. For instance, formal models may then include feed-backs from non-monetary to monetary variables. ${ }^{37}$ Besides, a conceptual anchoring of (more) aggregate indicators within a single accounting system may lead to more uniformity and more stability of definitions; if only, because in this way any adjustment should be weighed against its repercussions on the rest of the system.

Reliability is enhanced because the more data are confronted at a meso-level, the more logical identities can be checked. As the SSDS [United Nations, 1975] puts it: "components must add to totals; accounts must balance; prices and quantities must multiply out to values." (p.3). An obvious example concerns labour statistics. Confronting these with the national accounts will facilitate the detection and correction of inconsistencies and weaknesses in both sources: on the one hand, trends in employment and wage rates by economic activity must be plausible in the 1 ight of concomitant value-added estimates, and on the other hand,

[^47]the national accounts' assessment of changes in the wage bill by industry must agree with the sum of credible changes in related employment and wage rates by labour category. A similar argument applies to the supply side of the labour market.

Efficiency is served as this system may promote the usage of uniform units, classifications, concepts, etc. throughout a statistical system. One of the advantages of such a harmonization is that the matching of results from different surveys becomes much easier. In turn, that may imply that less questions per survey and perhaps even smaller samples are required. This will concomitantly reduce the respondent burden. It stands to reason that some groups of specialized users will then prefer a different classification or concept for a specific field of their interest. Evidently, such figures have less characteristics of a pure public good than an integrated data system and therefore the compilation of data according to such special purpose classifications, concepts, etc. may receive a somewhat lower priority in official statistics.

An important social concern is the level and composition of (un)employment. A SESAME commonly provides additional information on this issue, via a subdivision of total employment by type of person employed and industry of employment on the one hand and by household group and type of person employed on the other. These tables should then be classified in the same way as the concomitant labour income submatrices in the SAM proper; refer to the submatrices ( $3 A-3 H, 2 A-2 E$ ) and (4_6A-4_6F, 3A-3H), respectively, of table 3. Besides, these detailed employment figures and the concomitant labour income figures in the SAM should be consistent; in other words, dividing the latter by the former should yield plausible average wage rates in all cases. Evidently, an estimate of total employment requires that the selfemployed are also distinguished in the classification of employed persons; cf. tables 3 and 4.

As a next step, one may confront (1) the allocation of (imputed) labour incomes by category of employed persons to household subgroups as shown in the SAM; cf. submatrix (4_6A-4_6F, 3A-3H) in table 3, (2) a decomposition of these incomes into full-time equivalent employment and
average wage rates and (3) the potential labour force by household group and type of person (expressed in 'full-time' equivalents). This yields detailed information on the composition of unemployment and an aggregate indicator ('full-time equivalent unemployment') which is consistent with the other macro-economic indicators in the SESAME. Moreover, a basic unit in the Generation of Income Account (\#3) is the employed person. In so far as these units are resident, their total number agrees with employment in terms of person units and subtracting this from the potential labour force yields unemployment as it is conventionally defined.

Another example concerns the integration of data on literacy. If, for instance, employed persons are classified by education obtained, including a group which is supposedly illiterate (completed less than three years of primary school, say), and the same is done for the nonemployed potential labour force by socio-economic subgroup, a SAM plus concomitant population and employment matrices would reveal, e.g.:

- Adult literacy by socio-economic subgroup.
- Labour force participation rates of literate and illiterate citizens, by socio-economic subgroup.
- Employment, average wage rate and labour income by socioeconomic background and by education obtained of the employed persons, the illiterate being a separate category.
- Employment, average wage rate and labour income by education obtained (including the illiterate as a separate subgroup) and by industry in which these employed persons are engaged.
- National aggregates for these variables which are consistent with the more detailed data.

Such a data system would encompass more than a simple calculation of the literacy rate: it would enable analyses into the causes and consequences
of this phenomenon and into the macro-economic trade-offs of policies which aim at improving the situation. A similar argument applies to the incorporation of environmental issues in a SAM-framework (see Keuning [1992a]). ${ }^{38}$

### 6.2 Linkage of labour income and employment data in the SESAMEs for Indonesia

In order to illustrate the linkage of labour income data and employment figures in a SESAME, table 5 shows 1980 employment by labour category and industry in Indonesia, whereby the classifications are the same as in the previous table. The lower right-hand corner contains an estimate of aggregate 1980 employment in Indonesia, namely 57.1 million full-time worker equivalents. A similar table for 1975 registers 46.3 million worker equivalents [Keuning, 1993 (forthcoming)]. This implies an average growth rate of 4.2 per year. Juxtaposing this with the average annual growth rate of GDP at constant 1980 prices, estimated at 7.7\%, shows that employment growth was lagging behind, or, to put it more positively, that average labour productivity has increased substantially in Indonesia between 1975 and 1980.

These estimates of changes in real GDP and employment have been derived from SESAMEs for 1975 and 1980 that are both comparable and internally consistent. This applies not only to the macro-level, but also to a meso-level. Consequently, it can be analyzed which types of employment were not keeping pace with overall economic growth, or in which industries labour productivity grew so fast. In addition, it can be attempted to detect the causes of such developments, using e.g. multiplier analysis [Droog, 1992], or their consequences, e.g. for the income distribution [Keuning, 1992b]. Related economic and social indicators which can be derived from these SESAMEs are, among others: population growth, the change in the overall Consumer Price Index, the

[^48]
growth rate of real per capita Disposable Income, the reversal in the balance on current account of the Balance of Payments, shifts in overall income inequality, the increase in the average number of years of schooling of the potential labour force, the rise of per capita daily calorie intake in the poorest household subgroup, the increase in the fixed capital stock, etc. [Keuning, 1993 (forthcoming)]. ${ }^{39}$

Apart from a comparison with the concomitant 1975 data set, it might also be interesting to juxtapose the figures in this table and the previous one. For instance, average wage rates by type of employed person and industry can thus be obtained. It can be concluded that:

- The share of agricultural labour, rural labour, unpaid labour and female labour in total employment is considerably higher than the share of these categories in total labour income; related to this, their average wage rate is only $0.52,0.76,0.73$ and 0.68 , respectively, of the national mean.
- The share of food crops cultivation, textile manufacturing and personal and household services in total employment is considerably higher than the share of these industries in total labour income; related to this, the average wage rate in these industries is only $0.45,0.62$ and 0.66 , respectively of the national mean.
- The share of mining, finance and utilities in total employment is considerably lower than the share of these industries in total labour income; related to this, the average wage rate in these industries is $7.21,7.07$ and 3.50 , respectively of the national mean.
- The labour input of women was higher than that of men in restaurants and textile manufacturing. Female labour input was negligible in transport and fishery. In all industries except livestock and hotels, average wage rates of males were higher than those of females. The difference was particularly pronounced in

39. The most important indicator which is still lacking from these SESAMEs is an environmental policy indicator. The conceptual embedding of such an indicator in a SESAME-framework is set out in Keuning (1992a).
wood and wood products manufacturing and construction, quarrying and food processing. The divergence in wage rates by industry was more pronounced for women - varying between 0.50 and 10.37 times the national female average, than for men - varying between 0.43 and 6.57 times the national male average.

- In a wide range of industries most employment was in rural areas. This applied not only to agriculture, but also to all manufacturing industries except paper, metal products and other manufacturing, and to all services except hotels, other transport and comminication, finance, and real estate and business services. Yet, half of all employment in rural areas is in food crops cultivation. In all industries except finance average wages were higher in urban areas. The divergence in wage rates by industry was more pronounced in rural areas - varying between 0.58 and 9.55 times the national rural average, than in urban areas - varying between 0.40 and 4.49 times the national urban average.
- The proportion of the labour force that is self-employed varied enormously by industry: $1 \%$ or less in mining, finance, utilities and government, social, cultural and recreational services, and more than $75 \%$ in trade and transport services, restaurants, livestock and food processing. Converted to full-time equivalents, seven out of ten self-employed worked in two industries: food crops cultivation and trade and transport services. At the most detailed level of our computations, the average wage rates imputed to the self-employed are the same as those earned by their salaried colleagues. Nevertheless, at a more aggregate level their wage rate was much lower as they were over-represented in low paying labour categories and industries.
- The employment of each occupational category was very much concentrated in one or a few industries: 81\% of the agricultural workers was employed in food crops cultivation, $66 \%$ of the manual workers in wood and wood products manufacturing and construction, personal and household services, land transport and food processing, $61 \%$ of the clerical, sales and services workers in
trade and transport services and $76 \%$ of the professionals, technicians, managers and supervisors in government, social, cultural and recreational services. At the same time, table 5 shows that the employment in virtually all industries was dominated by one occupational category. Not surprisingly, the group of professionals, managers, etc. had the highest average wage rate in all industries, while agricultural and manual workers typically earned the least per hour. At the national level, the average wage of the former category was 7.1 times that of the agricultural workers. The variation across industries of average wage rates by occupational category was also substantial: e.g. for professionals, managers, etc. ranging from 0.28 to 4.87 times their national average.

This table may shed some light on the size and distribution of the demand for labour of various types. The full-fledged SESAME for Indonesia also contains tables on the supply side of the labour market. Using the same classification of employed persons as in tables 4 and 5, the allocation of labour income and employment to various household groups is shown. Confrontation with the potential male and female labour force then yielded labour force participation rates by sex and household group. In fact, the outcomes of this confrontation were originally not all plausible. As a consequence, the underlying sources have again been studied and corrected. In this way, we think that the construction of a consistent SESAME for Indonesia may have increased not only the relevance of both the national accounts and the labour data but also their reliability.

In conclusion of this paper, the usefulness of this kind of tables to an analysis of the current economic situation in Indonesia may be reviewed. For, as the tables relate to a situation of more than a decade ago, one might remark that we are dealing with economic history in this case. While acknowledging that for the time being SESAMEs will always become available with a delay, some comfort may be derived from the experience with the Input-Output approach. In the beginning, these tables were also rather out of date before they were published.

Nowadays, such matrices are a basic tool in the compilation of national
accounts in many countries. Eventually, SESAMEs may also serve to organize the annual compilation process of integrated statistics. For the time being, it is most expedient to compile SESAMEs for benchmark years only. More recent annual figures may then be revised such that the rates of change with respect to the benchmark year(s) are plausible.

In the Indonesian case, a SAM for 1985 has already been published [Biro Pusat Statistik, 1991] and another one for 1990 is in preparation. The 1985 SAM may need some adjustment in order to make it more comparable with the new 1975 and 1980 data sets. All in all, it stands to reason that in a few years time four SESAMEs are available, stretching 20 years through 1990. This enables all kinds of analyses in the causes and consequences of the structural adjustments which have occurred during this period. Such analyses may still be relevant to the economic and social policy-making of today.

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# ENVIRONMENT-RELATED EXTENSIONS OF INPUT-OUTPUT TABLES 

## Concepts and Applications

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## Introduction

The following contribution is based on considerations which have been developed by the author within the scope of a Eurostat project on environment-related extensions of input-output tables (contract no. 0880005). The results of this study had been used for elaborating Chapter VI (Input-output applications) of the SNA Handbook on Integrated Environmental and Economic Accounting (see United Nations, 1992b). The concepts of the System for Integrated Environmental and Economic Accounting (SEEA) which are described in this Handbook are strongly influenced by considerations which concepts could provide a useful data basis for input-output applications. Extended input-output tables seem to be the most suitable framework for analysing environmental-economic interrelationships within a country and on an international level (see also Beutel, 1983; Cumberland, 1971; Cumberland, Stram, 1974; Fфrsund, Strфm, 1972; Franz, 1988, 1989, 1991; Hetteling et al., 1985; Isard et al., 1968; Isard, 1969; Isard et al., 1972; Leontief, 1970, 1973; Leontief, Ford, 1971; Lehbert, 1972; Rose, Miernyk, 1989, paragraph 5.5; Schäfer, Stahmer, 1989). The following presentation of the concepts of input-output tables with environment-related extensions (part 1) and of possible applications (part 2 of the paper) aims at showing the usefulness of extended input-output tables for environmental-economic analysis. Further explanations of the concepts applied are given in the mentioned Handbook.

# 1 Concepts of input-output tables with environmentrelated extensions 

### 1.1 Overview

Environment-related extensions of input-output tables can be accomplished in $t h r e e s t e p s$ which represent three different levels of information:

```
- The first information level (A) comprises the
    traditioonal monetary data
    of input-output tables with further environment-
    related disaggregation. In this context, special
    attention can be given to the identification of
    monetary data connected with environmental protection
    activities. These activities could be treated as
    production activities independent of whether they are
    producing for third parties or for own purposes O&
    the respective economic unit.
```

- The second information level $(A+B)$ consists of the monetary data of level $A$ and, in addition, contains information in $p h y s i c a l$ terms on different types of economic uses of the natural environment (B-data). Examples of such uses are especially the depletion of raw materials and the discharge of residuals of economic activities into the natural environment. For achieving a comprehensive analysis of energy and material flows, additional physical information on the flows of goods and on the economic treatment (recycling) of residuals should be taken into account.
- The third information level ( $A+B+C$ ) comprises, in addition to information level $A+B, \quad i m p u t e d$ $c o s t s$ of depleting and degrading the natural environment by economic activities ( $C$ data). These data reflect a valuation of parts of the physical
flows recorded on the information level $A+B$.

Table 1 shows an input-output table with environmentrelated extensions according to the information level $A+B+C$ which contains the other information levels as well. The elements of the table indicate monetary data of the traditional national accounts (Aij), additional information in physical terms on the economic-environmental interrelationships ( $B_{i j}$ ) and imputed costs of depleting or degrading the natural environment ( $C_{i j}, i=1, \ldots, 15 ; j=1, \ldots, 11$ ). Table 1 describes physical ( $B_{i j}$ ) and monetary data ( $A_{i j}$ or $C_{i j}$ ) in a combined presentation. For each element of the table, physical data are shown together with the corresponding monetary values. Of course, some elements are represented only by monetary or physical
information. The elements $A_{i j}, B_{i j}$ and $C_{i j}$ can represent one figure only, a row or a column with figures or a complete matrix with several rows and columns. Further disaggration of the elements is of course possible (see United Nations, 1992b, especially section 3.4, pp. 160-164, and Table 3.8).

R O w s 1 to 4, 14, 18 and 19 of Table 1 correspond to items which are shown also in traditional inputoutput tables. In addition, the economic uses of natural assets are described in rows 5 to 13. If imputed environmental costs are recorded, the impacts on value added are indicated in rows 15 to 17. The colu m m classification of Table 1 is very similar to the traditional input-output classification. Extensions have been necessary only in the case of capital accumulation: In addition to the capital formation of produced assets, the capital accumulation of non-produced natural assets has been shown (column 9). In the following, the different environment-related extensions are described in more detail.

### 1.2 Environment-related disaggregation of traditional input-output tables <br> (information level A)

The uses of the products of branches are shown in rows 1 to 4. The product classification has been disaggregated with regard to two aspects:

- identification of the services of environmental protection activities (including recycling),
- disaggregation of product flows according to their origin (domestic, foreign). The data on imported (exported) products could be further subdivided by specific countries of origin (destination) if the international trade should be analysed in detail.

Environmental protection activities comprise two types of environmental protection:

- prevention of negative impacts of economic activities on the natural environment,
- restoration of economically caused deterioration of the natural environment.

Furthermore, recycling activities could be shown explicitly.

The production activities in the field of environmental protection comprise, differing from the SNA concepts (see United Nations, 1992a), not only external services for third parties, but also internal services for own purposes of the respective economic unit. In the conventional framework, these services are not treated as separate production activities. If they are " externalized", they obtain a value of gross output which can be estimated by summarizing

their costs (intermediate costs, depreciation, compensation of employees). The "externalized" services are delivered, in row 1 of Table 1 , together with the marketed external environmental services, to the branches which have used them for their own purposes.

In the context of information level $A$, the traditional column classification of input-output tables has been further disaggregated with regard to environmental protection activities. Thus, domestic production and capital formation have been shown in a breakdown by branches producing environmental protection services and other branches. A further subdivision of final consumption is not necessary because the necessary information on environmental protection expenditures is already achieved by a separate record of environmental protection services in the product classification (rows 1 and 3 of Table 1).

### 1.3 Environment-related extensions in physical terms (information level A + B)

In a second step, $p h y s i c a l d a t a d o n$ environmental-economic interrelationships are linked with the monetary data of traditional input-output tables (with disaggregated information on environmental protection activities). Physical data comprise information on supply and uses of products (rows 1 to 4 of Table 1), on the depletion of raw materials (rows 5 and 6) and on the discharge or the economic treatment of residuals (rows 8 and 9,12 and 13). The physical information on product, raw material and residual flows is shown in a breakdown by origin (domestic production, imports).

It is not proposed that the $p$ roduct flows be recorded in physical terms as complete as possible. Special attention should be given to those products which are especially important for analysing the uses
of raw materials and the disposal of residuals. Such products are e.g. heavy metals, types of energy and chemical products. The uses of recycled products are shown in Table 1 explicitly (see row 1).

The depletion of natural assets comprises the uses of biological, mineral and fossil raw materials for production and final consumption purposes (see rows 5 and 6, columns 1 to 3 ). These uses are connected with a decrease of the stocks of depletable natural assets in the country (row 5, column 9) or abroad (row 6). The depletion of raw materials of foreign origin does not comprise the imports of products within the scope of international trade but only the extraction of raw materials in extraterritorial regions (e.g. catching fish in the ocean). The record of raw materials depleted describes the imediate extraction within the natural
environment. Further uses of marketed raw materials are shown as uses of products. Thus, the depleted raw materials are only recorded as inputs of the primary production sector (agriculture, forestry, mining, energy) and, in exceptional cases, as inputs of household consumption. It has to be stressed that the depletion of biological resources not only comprises depletion of non-produced natural assets (like wild plants and animals) but also depletion of living biota which are "products" of the branches of agriculture, forestry, etc. In this case, depletion is recorded as the decrease of stocks of products (row 2, column 8).

The $r e s i d u a l s$ of economic activities can be discharged directly into the natural environment (Table 1 , rows 7 and 8) or can be further treated or stored in environmental protection or recycling facilities (rows 12 and 13). It has to be stressed that the record of residuals within an input-output framework will be incomplete. The main emphasis should be laid on types of residuals which could imply dangerous impacts on the
natural environment. The outcome of residuals can be caused by production activities (columns 1 and 2) or by household consumption activities (column 3).
Furthermore, all produced assets become residuals when they have not been further used economically (column 5 to 8). Uncontrolled landfills are treated as part of the natural environment. As far as residuals are discharged into the domestic natural environment (or stored uncontrolled), they are transferred from the discharging economic activities (columns 1 to 3, 5 to 8) to the non-produced natural assets (column 9). In the case of economic treatment or controlled storage, they are transferred to the environmental protection branches (column 1).

Residuals which originate from the restof $t h e \quad w o r l d$, are explicitly recorded. As far as residuals are transported by economic units from the rest of the world to the country and, without further treatment or controlled storage, discharged into the domestic natural environment, the respective flows are shown in row 9 of Table 1 . If residuals of foreign origin are treated or stored (in a controlled manner), they are recorded in row 8.

Only the $i m m e d i a t e ~ t r a n s i t i o n ~ o f ~ r e s i d u a l s ~$ from the responsible economic activities to the natural media is shown. The final destination of residuals is not recorded. A comprehensive analysis of transformation, assimilation and transport processes within the natural environment seems to be beyond the possibilities of an extended input-output framework. Such an analysis could be undertaken in ecological models which may be linked with input-output models in a second step.

Such a limitation of the presented input-output framework implies that the record of transboundary fowsof
residuals remains incomplete. Only if residuals are transported by produced vehicles to the rest of the world (e.g. by ship to parts of the ocean outside the country) or from the rest of the world to the respective country, such flows are recorded ("exports" of residuals: rows 8 and 12, column 10, "imports": rows 9 and 13, column 11).

### 1.4 Imputed costs of economic uses of the natural environment <br> (information level $A+B+C$ )

The third level of extending input-output tables Contains additional information on the
economicuse of the natural environment in monetary terms (C-data). This monetary information can be achieved by valuing physical data on the environmental-economic interrelationships (B-data). The different types of uses comprise the depletion of natural assets (raw materials), the economic use of land and the degradation of environmental media by the residuals of economic activities.

The economic uses of the different functions of the natural environment are valued only as far as they are connected with a quantitative or qualitative deterioration of the natural environment. The value of such a deterioration is estimated with the costs which would have occurred if the deteriorating impacts of economic activities (version IV. 2 of the SEEA, see United Nations, 1992b, subsection 4.2.3) had been prevented.

Such a valuation concept is used for both extending the costaccountsof deteriorating economic activities and correcting the asset accountsoof the different types of natural capital affected. The additional environmental costs have a positive sign, the corresponding decrease of the
value of natural assets a negative sign. In Table 1, the value of the economic uses of natural assets is recorded in rows 5 to 11. The economic uses comprise the depletion of natural assets (row 5 and 6), the use of land (row 7) and the discharge of residuals into the natural environment (row 8 and 9). Columns 1 to 7 record the costs of the different types of uses, columns 8 and 9 the corresponding decrease of the value of natural assets. Small differences between environmental costs and the value changes of natural assets occur because of transboundary environmental impacts of economic activities: Residuals can be transported from one country to another (see row 8, column 10; row 9, column 11), raw materials can be extracted in one part of the world and can, without entering the market as imported (exported) products, be transferred to another part of the world (e.g. fish of the ocean) (see row 6, column 11).

The calculation of prevention costs refers to both produced and non-produced natural assets. In the case of $p r o d u c e d n a t u r a l a s e t s$ which comprise only produced biological assets, environmental costs are estimated only as far as the market valuation of produced biota differs from the values according to the prevention cost approach (see row 5, column 8).

The quantitative and qualitative level of the natural environment can not only be decreased but also increased by economic activities. In this case which comprises especially economic activities aiming at the restoration of natural assets economically affected, the corresponding costs are treated as (positive) gross capital accumulation of the respective natural assets. Thus, cost items are recorded with negative sign, capital accumulation items with positive sign (see row 10 of Table 1).

In the case of environmental costs connected with the residuals of produced assets, it is recommended to $s h i f t$ the environmental costs from the asset accounts to the cost accounts of those branches which have used the respective natural assets (see row 11 of Table 1).

The method for valuing economic uses of natural assets corresponds to the $v a l u a t i o n$ method applied in the case of produced assets. In both cases, costs are estimated which would have occurred for maintaining the qualitative and quantitative level of the respective assets. In the extended input-output table, the depreciation of produced assets is recorded twice, as (positive) cost item (see row 14, column 1 and 2) and as (negative) change of asset values (see row 14, columns 5, 6 and 8).

It has been discussed controversially whether the additional imputations of environmental deterioration costs should imply modifications of the value added of responsible branches and of the asset accounts. The extended input-output framework presented in this contribution permits three different concepts for treating imputed environmental costs:

1. Environmental costs at maintenance values (based on the costs of prevention activities) could be subtracted from (net) value added. The diminished values are called eco value added (total: eco domestic product, EDP). The eco value added is shown in row 15 of Table 1 (columns 1 and 2), together with the corresponding modifications of capital accumulation (columns 8 and 9). Environmental costs of household consumption activities (column 3) could be treated as additional item for modifying the net domestic product (row 15, column 3).
2. The eco value added (eco domestic product) at market values could be calculated which can be derived from net value added (net domestic product) by subtracting only environmental costs at market values (see United Nations, 1992b, section 4.2.2). These costs comprise volume changes of natural assets only if they are caused by economic uses and if they are connected with market value changes of the non-produced natural assets. Such changes are presently recorded as other volume changes in the asset accounts of the conventional SNA (see United Nations, 1992a). The transition from maintenance to market valuation is shown in row 16 of Table 1.
3. If environmental costs neither at maintenance values nor at market values should be subtracted from net value added, a further balancing item can be introduced which is called eco margin (see row 17). The totals of rows 16 and 17 which reflect imputed environmental costs with negative sign, could be interpreted in this case as subsidies of the natural environment.

A numerical example of the extended input-output table described in this contribution is given in Chapter VI (table 6.2) of the mentioned Handbook (see United Nations, 1992b).

## 2 Environment-related input-output analysis

In the following, some relatively simple types of input-output models are presented. These types of $m o d e l s$ have a more or less
illustrativecharacter only. Completeness is not the objective. Special attention is given to input-output models which link different data sets, especially physical data with monetary data and different types of physical data. Further work has to be done to develop models which might be more comprehensive without being too complicated. The abbreviations of the matrices and vectors used are explained in an Annex.

An overview on the different types of environmentrelated input-output analysis described in this contribution is given in Table 2. After an introductory section (2.1) which gives some general explanations of input-output analysis, four types of in putoutput models are presented:

- Analysis of monetary flows of environmental protection activities, including an extension of the production boundary in the case of internal environmental protection activities, (section 2.2). The analysis aims at determining the economic importance of environmental protection activities and to identify the specific burden of environmental protection costs directly and indirectly associated with the production of specific branches or product groups.
- Analysis of physical flows of natural raw materials, produced goods and residuals (section 2.3). These physical flows are linked to monetary data without introducing imputed envirormental costs. The analysis especially aims at

Table 2: Environmemt-related Input-output analysls

studying the international interrelationships with regard to the depletion of natural assets, the production of goods and the destination of residuals. Furthermore, data on the economic use of raw materials and on the output of residuals are linked with the flows of produced goods. These linkages allow applications of the concepts of material/energy balances.

- Analysis of $i m p u t e d$ environmental costsof maintenance values (section 2.4). The analysis especially aims at determining indirect imputed environmental costs connected with international trade.
- Analysis of the $i m p a c t s$ of changes in $t n^{n}$ structure of inputs and in the structure of final uses connected with activities for maintaining naturalassets (section 2.5). In a first step, the immediate impacts of maintenance activities on economic structures are introduced as exogeneous changes. In a second step, the indirect effects of these structural changes on the use of raw materials and on the output of residuals are analyzed. Such models are, of course, based on the simple assumption of input-output analysis and could be used only for achiving some preliminary insight into the economic and environmental implications of strategies for maintaining natural assets.


### 2.1 General explanations of input-output analysis

The basic data of input-output analysis are the $m \circ n e t a r y$ figures of the tradition a input-output table (information level A). As previously explained, these data have been slightly modified by externalizing internal
environmental protection activities. These data are shown as elements $A_{i j}, a_{i j},(i=1, \ldots 19 ; j=1, \ldots$, 11) in Table 1. The capital letters denote matrices (with normally more than one row or column); the small letters denote vectors (row vector: one row, column vector: one column). For analysing these elements, it is useful to define matrices which comprise not one element of the table but a set of elements:
(1) $\quad X_{\text {dom }}=\left[\begin{array}{ll}A_{1.1} & A_{1.2} \\ A_{2.1} & A_{2.2}\end{array}\right]$
(2) $\quad X_{\text {imp }}=\left[\begin{array}{ll}A_{3.1} & A_{3.2} \\ A_{4.1} & A_{4.2}\end{array}\right]$
(3) $\quad \mathbf{Y}_{\text {dom }}=$
$=\left[\begin{array}{cccccccc}A_{1.3} & A_{1.4} & 0 & 0 & 0 & 0 & 0 & 0 \\ A_{2.3} & A_{2.4} & A_{2.5} & A_{2.6} & A_{2.7} & A_{2.8} & A_{2.9} & A_{2.10}\end{array}\right]$
(4) $\quad \mathbf{Y}_{\text {imp }}=$
$=\left[\begin{array}{cccccccc}A_{3.3} & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ A_{4.3} & 0 & A_{4.5} & A_{4.6} & A_{4.7} & A_{4.8} & 0 & A_{4.10}\end{array}\right]$
(5) $\quad Z=\left[\begin{array}{ll}A_{14.1} & A_{14.2} \\ A_{18.1} & A_{18.2}\end{array}\right]$
(6) $\quad q=\left[\begin{array}{ll}a^{\prime}{ }_{19} & a^{\prime} 19.2\end{array}\right]^{\prime}=\left[\begin{array}{l}a_{1} .11 \\ a_{2} .11\end{array}\right]$

$$
\begin{align*}
& \mathbf{X}=\mathbf{X}_{\text {dom }}+\mathbf{X}_{\text {imp }}  \tag{7}\\
& \mathbf{Y}=\mathbf{Y}_{\text {dom }}+\mathbf{Y}_{\text {imp }} \tag{8}
\end{align*}
$$

$X$ indicates the data of the first quadrant of the input-output table showing the intermediate use of products. X comprises the submatrices $X_{\text {dom }}$ (intermediate use of domestic products) and $X_{i m p}$ (intermediate use of imported products). Y denotes the data of the second quadrant which describes the final uses of products ( $\mathrm{Y}_{\text {dom: }}$ domestic products, $\mathrm{Y}_{\mathrm{imp}}$ : imported products). Matrix 2 indicates the data of the third quadrant of the input-output table which comprises, according to the traditional concepts, the use of produced fixed assets (depreciation) and net value added. $q$ denotes the gross output of the branches.

The matrices $A_{i j}$ normally consist of more than one vector and the vectors contain more than one element. Row vectors are described as transposed column vectors, for example $q$ is a column vector and $q^{\prime}$ a row vector (with the same elements). The models also use diagonal matrices which have the elements of a row or column vector in the diagonal. All other elements are zero. These diagonal matrices are described different from the denotation of the other matrices with the small letters of the vector shown in the diagonal with an additional subscript ^, e.g.

$$
\hat{a}=\left[\begin{array}{lll}
a_{1} & 0 & 0 \\
0 & a_{2} & 0 \\
0 & 0 & a_{3}
\end{array}\right] \text { with } a=\left[\begin{array}{l}
a_{1} \\
a_{2} \\
a_{3}
\end{array}\right]
$$

Inverse matrices are specified by the subscript ${ }^{-1}$, e.g. $A^{-1}$ is the inverse (matrix) of $A$ :
$I=A A^{-1}$

The identity matrix $I$ denotes a diagonal matrix with the unit vector e in the diagonal, e.g.
$I=\hat{e}=\left[\begin{array}{lll}1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1\end{array}\right]$ mit e$=\left[\begin{array}{l}1 \\ 1 \\ 1\end{array}\right]$

The following calculations require some coefficient matrices
(9) $X_{\text {dom }}^{q}=x_{d o m} \hat{q}^{-1}$
(10) $\mathrm{x}_{\text {imp }}^{q}=\mathrm{x}_{\text {imp }} \hat{q}^{-1}$
(11) $X^{q}=X \hat{q}^{-1}$
(12) $\mathrm{z}^{\mathrm{q}}=\mathrm{z} \hat{\mathrm{q}}^{-1}$

These matrices show the relations between inputs (intermediate inputs, gross value added) and gross output. $q^{\wedge}-1$ denotes a diagonal matrix with the reciprocal elements of vector $q$ in the diagonal.

The different matrices are connected in the following manner:
(13) $q=X_{d o m}^{q} q+Y_{\text {dom }} e$
$\mathrm{X}_{\text {dom }} \mathrm{q}$ indicates the row totals of the matrix of intermediate uses of products; $\mathrm{Y}_{\text {dom }} \mathrm{e}$ denotes those of the matrix of final uses (e: unit vector, see above).

The row totals of the matrices of final uses are described in the following manner:
(14) $\quad Y_{\text {dom }}=Y_{\text {dom }} E$
(15) $y_{\text {imp }}=Y_{\text {imp }} e$

$$
\begin{equation*}
\mathbf{y}=\mathbf{y}_{\mathrm{dom}}+\mathbf{y}_{\mathrm{imp}} \tag{16}
\end{equation*}
$$

Equation (13) could be used for deriving a fundamental relationship between final uses of products and gross output which is directly and indirectly necessary to produce these final products:
(17) $q-X_{\text {dom }}^{q} q=Y_{\text {dom }}$
(18) $\left[I-X_{\text {dom }}^{q}\right] \quad q=y_{\text {dom }}$
(19) $\left[\mathrm{I}-\mathrm{x}_{\mathrm{dom}}^{\mathrm{q}}\right]^{-1}\left[\mathrm{I}-\mathrm{x}_{\mathrm{dom}}^{q}\right] \mathrm{q}=$ $=\left[I-X_{d o m}^{q}\right]^{-1} y_{\text {dom }}$
(20) $\quad \mathrm{q}=\left[\mathrm{I}-\mathrm{X}_{\mathrm{dom}}^{\mathrm{q}}\right]^{-1} \mathrm{y}_{\mathrm{dom}}$

The meaning of equation (20) could be clarified by using another type of presentation of the inverse coefficients:
(21) $\quad q=\left[I+X_{d o m}^{q}+x_{d o m}^{q} x_{d o m}^{q}+\ldots\right] y_{d o m}=$

$$
=y_{d o m}+x_{d o m}^{q} y_{d o m}+x_{d o m}^{q} x_{d o m}^{q} y_{d o m}+\ldots
$$

The gross output of the branches comprises domestic final products ( $Y_{\text {dom }}$ ), direct intermediate inputs for producing final products ( $\mathrm{X}_{\mathrm{dom}} \mathrm{Y}_{\text {dom }}$ ), the intermediate inputs for producing the mentioned direct intermediate inputs ( $X_{\text {dom }} X_{\text {dom }} Y_{\text {dom }}$ ), and so forth.

If it is intended to show the gross output directly and indirectly required to produce the products of the
 uses, the inverse coefficients are not multiplied by the row totals of the second quadrant but by the complete matrix $Y_{\text {dom }}$ :

$$
\begin{equation*}
Q_{Y}^{\star}(\operatorname{dom})=\left[I-X_{d o m}^{q}\right]^{-1} Y_{d o m} \tag{22}
\end{equation*}
$$

$Q^{*}{ }_{Y}($ dom $)$ indicates a matrix showing the gross output necessary to produce the final products of the different categories of final uses in the columns, the rows describe the values of the different product groups required.

If gross output is associated with the different groups of final products, diagonal matrix $y^{\wedge}$ dom has to be used:

$$
\begin{equation*}
Q_{Y}^{*}(\text { dom })=\left[I-X_{d o m}^{q}\right]^{-1} \hat{Y}_{d o m} \tag{23}
\end{equation*}
$$

For associating components of $g r o s s \quad v a l u e$ a d ded (use of produced fixed assets and net value added in Table 1 , rows 14 and 18) and of importedintermediate productse (Table 1 , rows 3 and 4) with final domestic products, gross output shown in equations (21) to (23) is multiplied by the respective input coefficients:

$$
\begin{align*}
x_{i m p} & =x_{i m p}^{q} q=  \tag{24}\\
& =x_{i m p}^{q}\left[I-x_{d o m}^{q}\right]^{-1} y_{\text {dom }}
\end{align*}
$$

$$
\begin{equation*}
X_{Y}^{\star}(\text { imp, dir })=X_{i m p}^{q} Q_{Y}^{\star}(\text { dom })= \tag{25}
\end{equation*}
$$

(27) $z=z^{q}\left[I-x_{d o m}^{q}\right]^{-1} y_{\text {dom }}$

$$
\begin{equation*}
z_{Y}^{*}(\operatorname{dom})=Z^{q}\left[I-X_{d o m}^{q}\right]^{-1} Y_{d o m} \tag{28}
\end{equation*}
$$

$$
\begin{equation*}
z_{y}^{*}(\operatorname{dom})=z^{q}\left[I-x_{d o m}^{q}\right]^{-1} \hat{y}_{d o m} \tag{29}
\end{equation*}
$$

$x_{i m p}$ and $z$ are column vectors containing the row totals of matrices $X_{i m p}$ and $Z$.

On the assumption that domestic and imported products are produced with the same input structure, that amount of gross output can be calculated which is directly and indirectly necessary to produce
i mported intermediate and final
products. The total amount of gross output necessary in the home country and abroad comprises the following elements:

$$
\begin{align*}
Q_{Y}^{\star}= & {\left[I-x^{q}\right]^{-1} Y=}  \tag{30}\\
= & {\left[I-x_{d o m}^{q}\right]^{-1} Y_{d o m}+} \\
& +\left[I-x^{q}\right]^{-1} Y_{i m p}+ \\
& +\left[I-x^{q}\right]^{-1} x_{i m p}^{q}\left[I-x_{d o m}^{q}\right]^{-1} Y_{d o m}
\end{align*}
$$

In equation (30), (I-Xq) ${ }^{-1}$ denotes the inverse coefficients derived from the total intermediate inputs for producing $q$ (see equation (11)). Y indicates the total final uses of products (in a classification by product group and category of final uses). The first term of the right side of equation (30) denotes domestic gross output $Q^{*} Y(d o m)$, the second term, gross
output necessary to produce imported final products abroad. The third term indicates gross output directly and indirectly necessary to produce imported intermediate products. These products are related according to equation (25) - to final products $Y$.

To show the interrelationship between total gross output and the different $g r o u p s \quad o f \quad f i n a l$ products, the following equation could be used:

$$
\begin{align*}
Q_{Y}^{*}= & {\left[I-x^{q}\right]^{-1} \hat{y}=}  \tag{31}\\
= & {\left[I-x_{d o m}^{q}\right]^{-1} \hat{\mathbf{y}}_{\text {dom }}+} \\
& +\left[I-x^{q}\right]^{-1} \hat{\mathbf{y}}_{\text {imp }}+ \\
& +\left[I-x^{q}\right]^{-1} \hat{x}_{i m p}^{q}\left[I-x_{d o m}^{q}\right]^{-1} \hat{Y}_{d o m}
\end{align*}
$$

If further information on foreign input structures for producing imports is available, equation (30) could be extended:

$$
\begin{align*}
& Q_{Y}^{*}=\left[I-X_{d o m}^{q}\right]^{-1} Y_{d o m}+  \tag{32}\\
& +\left(\left[I-X^{q}(1)\right]^{-1} Y_{i m p}(1)+\right. \\
& \left.+\ldots+\left[I-x^{q}(n)\right]^{-1} y_{i m p}(n)\right)+ \\
& +\left(\left[I-x^{q}(1)\right]^{-1} \quad x_{i m p}^{q}(1)\right. \\
& \text {. }\left[\mathrm{I}-\mathrm{X}_{\mathrm{dom}}^{\mathrm{q}}\right]^{-1} \mathrm{Y}_{\mathrm{dom}}+\ldots+ \\
& \left.+\left[I-x^{q}(n)\right]^{-1} \quad x_{i m p}^{q}(n)\right) \quad . \\
& \left.\left[I-X_{d o m}^{q}\right]^{-1} Y_{d o m}\right)
\end{align*}
$$

$\mathrm{X}^{\mathrm{q}}(\mathrm{k})(\mathrm{K}=1, \ldots, \mathrm{n})$ denotes input structure in country $k$; $Y_{i m p}(k)(k=1, \ldots, n)$ indicates final products imported from country $k$ and $X_{i m p}(k)$ denotes input coefficients of intermediate products imported from country $k$. In implementing the models described above, it may be sufficient to use the input structures of one or two countries which have produced imported products and could represent the other countries of origin of imports. For simplifying the equations in the following subsections, it will be assumed that the domestic input structures are also representative of the production abroad.

### 2.2 Input-output analysis of envirommental protection activities

For purposes of environmental policy, the economic importance of environmental protection a ctivities has been questioned. In this context, attention has been focussed on not only aggregates but also on further disaggregation of the types of environmental protection activities and on the development of these activities over time. In many cases, monetary data on enviromental protection activities have been related to macro-economic aggregates like gross domestic product. These studies require that the concepts of the aggregates compared are really comparable. Besides macro-economic considerations, it appears important to identify the specific burden of environmental protection costs which could be directly and indirectly associated with specific branches or product groups.

Both types of studies could be implemented by using in $\mathrm{f} u \mathrm{t}$ - output models similar to the
models presented in the preceding subsection (see also Schafer, Stahmer 1989). By applying input-output analysis, it is possible to identify an aggregate of environmental protection costs which does not contain double counting. This aggregate is comparable to the domestic product or to other macro-economic aggregates. Furthermore, input-output models can reveal costs which are indirectly induced by producing specific products.

As a starting point for analyzing environmental protection activities, the total amount of environmental protection $c \circ s t s$ could be estimated. This total would contain the gross output of (external or externalized) environmental protection activities (in Table l: $a_{19.1}=a_{1.11}$ ) and imports of environmental protection services (a3.11). Gross capital formation with regard to environmental protection activities ( $A_{2} .5$ and $A_{4} .5$ ) has not been taken into account because these costs have already been periodized as depreciation (use of fixed produced capital) in the cost accounts of environmental protection activities ( $\mathrm{A}_{14} .1$ ).

If interest is expressed in estimating environmental protection expenditures as well as environmental protection costs, the aggregate based on expenditures could be derived by exchanging the values of depreciation and gross capital formation:

```
    Gross output of environmental protection
    services (alg.1)
+ imported environmental protection services (a3.11)
= total environmental protection costs
- depreciation of fixed produced assets used for
    environmental protection purposes (A14.1)
+ gross capital formation for environmental protection
    purposes (A2.5 and A4.5)
= total environmental protection expenditures.
```

The total environmental protection costs could be related to the $t \circ t a l$ supply of products:

$$
\left(a_{19.1}+a_{3.11}\right):\left(a_{19.1}+a_{19.2}+a_{3.11}+a_{4.11}\right)
$$

It seems to be more important to calculate the relationship of environmental protection costs to national income or domestic product defined on a net basis. This concept implies that products produced and used for the production of other products (domestic intermediate products) in the same country are not taken into account. For purposes of suitable comparisons, environmental protection costs are also calculated on a net basis.

It seems preferable to achieve this aggregate in $t w o s t e p s: \quad$ First, the aggregate of environmental protection costs is modified to obtain comparability with the total of final uses of products (Y). In a second step, comparability with the domestic product is achieved.

The aggregate of environmental protection costs comparable with the $t \circ t a l f i n a l y s e s$ of products comprises the following terms:

$$
\begin{align*}
& U_{Y}^{*}=\left[\begin{array}{c}
x_{i m p}^{q} \\
-\frac{\bar{q}^{q}}{}
\end{array}\right]\left[I-x_{d o m}^{q}\right]^{-1} Y_{d o m}(u)+  \tag{33}\\
& +\left[\begin{array}{l}
\text { Yimp_ }^{(u)} \\
0
\end{array}\right]+ \\
& +\left[\begin{array}{c}
x_{i m p}^{q} \\
-\frac{z^{q}}{q}
\end{array}\right]\left[I-x_{d o m}^{q}\right]^{-1} \cdot x_{d o m}^{q}(u) \cdot
\end{align*}
$$

$$
\begin{aligned}
& \text { - }\left[I-X_{d o m}^{q}(n u)\right]^{-1} Y_{d o m}(n u)+ \\
& +\left[\begin{array}{c}
x_{i \underline{m p}}^{q}(u) \\
0
\end{array}\right]\left[I-x_{d o m}^{q}(n u)\right]^{-1} Y_{d o m}(n u)
\end{aligned}
$$

Bquation (33) is derived from disaggregating the data on final uses (equations (3) and (4)) and the coefficient matrices of intermediate inputs (equations (9) and (10)). This disaggregation aims at separately identifying intermediate and final uses of environmental protection services (index: u). The necessary matrices can be derived from Table l:
(34) $Y_{\text {dom }}(u)=$
$=\left[\begin{array}{cccccccc}{ }^{A_{1.3}} & A_{1.4} & 0 & 0 & 0 & 0 & 0 & A_{1.10} \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0\end{array}\right]$
(35) $\mathbf{Y}_{\text {dom }}(\mathrm{nu})=$
$=\left[\begin{array}{cccccccc}0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ A_{2.3} & A_{2.4} & A_{2.5} & A_{2.6} & A_{2.7} & A_{2.8} & A_{2.9} & A_{2.10}\end{array}\right]$
(36) $\mathbf{Y}_{\text {imp }}(\mathbf{u})=$
$=\left[\begin{array}{cccccccc}\mathrm{A}_{3.3} & \mathrm{~A}_{3.4} & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0\end{array}\right]$
(37) $Y_{\text {imp }}(n u)=$
$=\left[\begin{array}{cccccccc}0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ \mathbf{A}_{4.3} & \mathbf{A}_{4.4} & \mathbf{A}_{4.5} & \mathbf{A}_{4.6} & \mathbf{A}_{4.7} & \mathbf{A}_{4.8} & 0 & \mathbf{A}_{4.10}\end{array}\right]$
with
（38）$Y=Y_{\text {dom }}(u)+Y_{\text {dom }}(n u)+Y_{i m p}(u)+Y_{i m p}(n u)$
（39）$x_{\text {dom }}^{q}(u)=\left[\begin{array}{cc}A_{1.1} & A_{1.2} \\ 0 & 0\end{array}\right] \hat{q}^{-1}$
（40）$\quad x_{d o m}^{q}(n u)=\left[\begin{array}{cc}0 & 0 \\ A_{2.1} & A_{2.2}\end{array}\right] \hat{q}^{-1}$
（41） $\mathrm{x}_{\mathrm{imp}}^{\mathrm{q}}$
$(u)=\left[\begin{array}{cc}A_{3.1} & A_{3.2} \\ 0 & 0\end{array}\right] \hat{q}^{-1}$
（42）$\quad x_{i m p}^{q}(n u)=$


The four terms on the right side of equation（33）mean：
－Term one indicates all primary inputs（imported intermediate products，components of gross value added）which are directly or indirectly required to produce domestic environmental protection services for final uses．The total of this term corresponds to the total value of domestic final environmental protection services $Y_{\text {dom }}(u)$ ．
－Term two denotes imported environmental protection services for final uses．These services are treated as primary inputs in the same way as imported environmental protection services for intermediate uses．
－Term three cor．こai．：s the primary inputs which are directly and ：．．dizectly necessary to produce environmentaン ミこここection services used as intermediate ：－ேさここミ for producing products not
directly or indirectly connected with the production of environmental protection services.

- Term four denotes imported environmental protection services used as intermediate inputs for producing directly or indirectly the products mentioned which are not connected with environmental protection activities.

It can be shown that $U^{*} Y$ is $s m a l l e r$ than the $t \circ t a l \sup p l y$ of envirommental protection services $U\left(=d_{19.1}+a_{3} .11\right)$ to an amount which comprises all intermediate environmental protection services directly or indirectly used for the production of environmental protection services.

The row ciassification of merix $U^{*} Y$ in equation (33) combines the row classification of imported products (see Table 1, rows 3 and 4) with the components of gross value added (use of produced fixed assets, net value added, see rows 14 and 17). The
 the categories of final uses (with possible further disaggregations, see columns 3 to 10 in Table 1).

For separately analysing imported intermediate products, depreciation and net value added connected with environmental protection services, it seems appropriate to define three submatrices which have the same column classification as $U^{*} Y$ but which specify the impacts on imports (imp), depreciation (dep) and net value added (nva):

$$
\begin{equation*}
\mathrm{U}_{\mathrm{Y}}^{\star}=\mathrm{U}_{\mathrm{Y}}^{\star}(\operatorname{imp})+\mathrm{U}_{\mathrm{Y}}^{\star}(\text { dep })+\mathrm{U}_{\mathrm{Y}}^{\star}(\text { nva }) \tag{43}
\end{equation*}
$$

This separation facilitates the comparison with aggregates describing the whole economy, $U^{*} Y$ contains all environmental protection services comparable with
the total amount of final uses of products. If imported environmental protection services are neglected, a comparison of $\left[U^{*} Y(d e p)+U^{*} Y\right.$ (nva)] with the gross domesticoproduct is possible. If only data of $U^{*} Y$ (nva) were taken into account, the corresponding aggregate would be $n$ e $t$ domesticoproduct.

If the environmental protection services should not be associated with the categories but with specific product groups of final uses, the following equation could be used instead of equation (33):
(44) $\quad U_{Y}^{\star}=\left[\begin{array}{c}x_{i}{ }^{q}{ }_{-} \\ -\frac{q^{q}}{}\end{array}\right]\left[I-x_{d o m}^{q}\right]^{-1} \hat{\mathbf{y}}_{\text {dom }}(u)+$

$$
+\left[\begin{array}{c}
\hat{\mathbf{y}}_{\text {imp }}(\mathrm{u}) \\
0
\end{array}\right]+
$$

$$
+\left[\begin{array}{c}
x_{i m p}^{q} \\
-\frac{\bar{q}}{q}
\end{array}\right]\left[I-x_{d o m}^{q}\right]^{-1} \quad x_{d o m}^{q} \quad(u)
$$

$$
\cdot\left[I-x_{d o m}^{q}(n u)\right]^{-1} \hat{y}_{\text {dom }}(n u)+
$$

$$
+\left[\frac{x_{i \underline{m p}}^{q}}{-\underset{0}{q}(u)}\right]\left[I-x_{d o m}^{q}(n u)\right]^{-1} \hat{y}_{d o m}(n u)
$$

$U^{*}{ }_{Y}$ differs from $U^{*} Y$ in the matrices of final uses of products: Instead of matrices $Y$ which are classified rowwise by product groups and columnwise by category of final use, diagonal matrices $\mathrm{Y}^{\wedge}$ are used which contain the row totals of the corresponding $Y$-matrices as
elements in the diagonal. Thus, the following definitions hold (with the unit vector e):
(45) $Y_{\text {dom }}$
(u) $=Y_{\text {dom }}$
(u) e
(46) $Y_{\text {dom }}(n u)=Y_{\text {dom }}(n u) e$
(47) $Y_{\text {imp }}(u)=Y_{\text {imp }}(u) e$
(48) $Y_{\text {imp }}(n u)=Y_{\text {imp }}(n u) e$ with

$$
(49) Y=Y e=Y_{\text {dom }}(u)+Y_{d o m}(n u)+
$$

$$
+y_{i m p}(u)+Y_{i m p}(n u)
$$

### 2.3 Input-output analysis of the physical good, raw material and residual flow accounts

Physical and monetary data of the extended input-output table could be linked in manifold ways. In the following, the presentation of analytical models is limited to two examples:

- international
interrelationship with regard to the depletion of natural assets, the production of goods and the destination of residuals,
- 1 ink a ge of data on the economic use of depletable natural assets (raw materials) and on the output of the residuals of production and final consumption activities with the flows of produced goods.

The structure of the input-output models presented here has been developed to be a s simply a s possi ble. More complex input-output models
which for example treat final uses as endogenous variables and take into account stock data, are not described. Further simplifications are necessary with respect to the "production" and destination of residuals (discharge into the natural environment, treatment, storage etc.).

The following three subsections deal with produced goods models (2.3.1), with their linkage with raw material flows (2.3.2), and with linked goods and residual models (2.3.3).

### 2.3.1 Produced goods models

The following equations denote the matrices of physical data on goods used in an extended input-output table and their linkage with monetary data on gross output:

with




It should be stressed that matrices $G_{X}, G_{X}{ }^{q}$ and $G_{Y}$ do, of course, also denote flows of services as long as a physical equivalent is associated with them. In the following, it is assumed that the use of products in physical terms is limited to goods only. Furthermore, it has to be emphasized that the matrices of physical data on the use of goods do not have to be complete with regard to the different types of goods used in the home economy. In most cases, inputoutput analysis will concentrate on the use of specific types of goods which are important from the point of view of environmental analysis.
$G_{X}$ indicates the intermediate use of goods in physical terms (domestic goods: $\mathrm{G}_{\mathrm{X}_{\text {dom }}, ~ i m p o r t e d ~ g o o d s: ~} \mathrm{G}_{\mathrm{X}_{\mathrm{imp}} \text { ), }}$ $G_{Y}$ denotes the final use of goods in physical terms. $G_{X}$ and $G_{Y}$ comprise two classifications of goods (domestic resp. imported goods ). The column classification of $G_{X}$ refers to branches, that of Gy to categories of final uses (with possible further subdivisions according to purpose, types of assets, using branches, countries receiving the export goods, etc.). The coefficients $\mathrm{GX}_{\mathrm{X}}{ }^{\text {g }}$ link the physical data on flow of goods with the monetary data on gross output.

For analyzing the $i n t e r n a t i o n a l$ interrelationships of producing and using goods, the linkage between physical and monetary flows of goods are described by extending equation (30). The total amount of goods in physical terms directly and indirectly required, in the country as well as in the rest of the world, to produce the products for final
uses $y$ could be calculated by using the following equation:

The first term on the right side of the equation (53) denotes total intermediate goods required; the second term indicates physical data on final goods.

If the intermediate goods are differentiated with regard to their 0 ri g i n (domestic production, imports), equation (53) could be split up into further elements:
(54) $\quad G_{Y}^{*}=\left(\left[\begin{array}{c}G_{X}^{q} \\ --\frac{\text { dom }}{} \\ 0\end{array}\right]+\left[\begin{array}{c}0 \\ -\bar{G}_{X_{i m p}}\end{array}\right]\right)$.
. $\left[I-x_{d o m}^{q}\right]^{-1} Y_{d o m}+x_{i m p}^{q}$.

$$
\cdot\left[I-x_{d o m}^{q}\right]^{-1} Y_{d o m}+x^{q}\left[I-x^{q}\right]^{-1}
$$

$$
\cdot \mathrm{x}_{\mathrm{imp}}^{\mathrm{q}}\left[\mathrm{I}-\mathrm{x}_{\mathrm{dom}}^{\mathrm{q}}\right]^{-1} \mathrm{Y}_{\mathrm{dom}}+\mathrm{Y}_{\mathrm{imp}}+
$$

$$
\left.+x^{q}\left[I-x^{q}\right]^{-1} Y_{i m p}\right)+
$$

$$
\begin{align*}
& G_{Y}^{*}=\left[\begin{array}{l}
G_{X_{d o m}}^{q} \\
-G_{X_{i m p}}
\end{array}\right]\left[I-X^{q}\right]^{-1} Y+  \tag{53}\\
& +\left[\begin{array}{l}
\mathrm{G}_{\mathbf{Y}_{\text {dom }}} \\
\bar{G}_{\mathbf{Y}_{\text {imp }}}^{\text {dim }}
\end{array}\right]
\end{align*}
$$

$$
+\left[\begin{array}{c}
\mathrm{G}_{Y^{\text {dom }}} \\
-\underset{0}{ }
\end{array}\right]+\left[\begin{array}{c}
0 \\
\mathbf{G}_{Y_{i m p}}^{---}
\end{array}\right]
$$

It is assumed that countries producing imported products and the home country have the $s$ a me in $\mathrm{n} u \mathrm{t}$ structures. Furthermore, it should be mentioned that the goods required from abroad may be directly or indirectly produced with goods which have been exported to the respective countries.

In comparison to the analysis of gross output in equation (30), the description has been shifted to a preceding stage of production. Instead of gross output which is directly or indirectly required to produce domestic final products $\left[\left(I-X_{d o m}\right)^{-1} Y_{\text {dom }}\right]$, the physical flows of goods are described which have been necessary to produce these values of gross output (see $\mathrm{F}_{2} .1$ and F3.1). This shift was obtained by multiplying the monetary data on gross output by the coefficients showing the relationship between physical goods inputs and monetary product outputs.

Similar to the procedure described in equation (54), the flows of physical goods could also be related to the various $p r o d u c t \quad g r o u p s \quad o f$ finaluses:

$$
\begin{align*}
G_{y}^{*} & =\left[\begin{array}{l}
G_{x_{d o m}}^{q} \\
--\frac{G^{\prime}}{-} \\
G_{x_{i m p}}
\end{array}\right]\left[I-x^{q}\right]^{-1} \hat{y}+  \tag{55}\\
& +\left[\begin{array}{l}
\hat{g}_{y_{\text {dom }}} \\
\overline{\hat{g}}_{y_{i m p}}
\end{array}\right]
\end{align*}
$$

$g_{Y_{\text {dom }}}$ and $g_{Y_{\text {imp }}}$ indicate the row totals of matrices $\mathrm{G}_{\mathbf{Y}_{\mathrm{dom}}}$ and $\mathrm{G}_{\mathbf{Y}_{\text {imp }}}$ :

```
(56) \(\quad g_{\mathbf{Y}_{\text {dom }}}=G_{\mathbf{Y}_{\text {dom }}} e\)
(57) \(g_{Y_{i m p}}=G_{Y_{i m p}} e\)
(e: unit vector)
```

These data on goods directly and indirectly used for producing other goods could be used not only for analyzing linkages between depleted raw materials, flows of goods and residuals but also for modelling the constituents of goods which might directly affect the health of living beings by consuming these goods. In the case of health affection, an important example could be the analysis of possibly poisonous chemicals contained in goods.

### 2.3.2 Raw materials models

In the following, models are described that link depletion of $n$ atural assets (raw materials) and its economic use with the monetary flows described in section 2.1. Special emphasis has been placed on the connections between the extraction of raw materials and flows of goods in physical terms and on the direct and indirect transboundary flows of raw materials. Again it has to be stressed that these models are also limited to specific raw materials and are not comprehensive and complete with regard to all types of raw materials.

The depletion and use of biological, fossil, mineral and other natural assets (such as water) comprise two steps:

- In a first step, depleted raw materials are shown as intermediate in puts of the depleting economic branches (such as agriculture, forestry, mining) or as immediate final consumption of households. The physical data on raw materials reflect the physical characteristics of the raw materials at $t h e m o m e n t o f$ depletion (e.g. weight of minerals extracted, weight of fish caught or timber cut). These data are shown in rows 5 (depletion of domestic natural assets) and 6 (depletion of foreign natural assets) of Table 1 (elements $\mathrm{B}_{5} .1$ to $\mathrm{B}_{5} .3, \mathrm{~B}_{6.1}$ and B6.2) .
- As long as the raw materials are not immediately consumed (e.g. as final consumption of households), they become - often after a first stage of treatment - part of $g r o s s o u t p u t$ of the depleting primary sector. Losses due to treatment and transportation often diminish the physical quantities of raw materials before they are marketable and thus reduce the quantities of goods which are part of gross output and available for further economic use. The quantities of marketable raw materials used as intermediate inputs are shown in rows 2 (domestic production) and 4 (imports) of Table 1.

To link physical data on depletion of natural assets with the amount of marketable raw materials (which are part of gross output of the primary sector), a
$b r e a k d o w n$ of the depletion of natural assets is necessary to distinguish the part
immediately consumed and the part becoming - after more or fewer quantitative
modifications - marketablegoods. A further breakdown is made with regard to whether raw materials are depleted by domestic economic units in the home country or in the rest of the world, e.g. fish in the ocean. The raw materials depleted by branches
could be disaggregated in the following manner:
(58) $\quad R_{X}=\left[\begin{array}{l}\mathrm{R}_{X_{\text {dom }}} \\ \bar{R}_{X_{\text {for }}}^{-}\end{array}\right]=\left[\begin{array}{ll}\mathrm{B}_{5.1} & \mathrm{~B}_{5.2} \\ \mathrm{~B}_{6.1} & \mathrm{~B}_{6.2}\end{array}\right]$
with
(59) $\quad R_{X}(q)=\left[\begin{array}{l}R_{X_{\text {dom }^{\prime}}(q)} \\ \bar{R}_{X_{\text {for }}}(\bar{q})\end{array}\right]$
(60) $\quad R_{X}(g)=\left[\begin{array}{l}R_{X_{\text {dom }^{\prime}}(g)} \\ \bar{R}_{X_{\text {for }}}(\bar{g} \bar{\prime}\end{array}\right]$
(61) $\quad R_{X}=R_{X}(q)+R_{X}(g)$
$\mathrm{R}_{\mathrm{X}}(\mathrm{q})$ denotes raw materials which are immediately consumed by the depleting branches. They have the usual characteristics of inputs and, therefore, are linked only with gross output $q$ in monetary terms, not with physical data on marketable raw materials which are part of the physical flows of goods (g). $\mathrm{R}_{\mathrm{X}}(\mathrm{g})$ indicates raw materials depleted by the primary sector which become - with quantities often reduced - part of the output of this sector. A further breakdown has been made with regard to the origin of raw materials (domestic: ${ }^{\mathrm{R}_{\mathrm{X}_{\text {dom }}}}$ foreign: $\mathrm{R}_{\mathrm{X}_{\text {for }}}$ ).

Raw materials immediately consumed by households are comparable with the materials of matrix $\mathrm{R}_{\mathrm{X}}(\mathrm{q})$. It is assumed that these raw materials are depleted only in the home country:
(62) $\mathrm{R}_{\mathbf{Y}}=\left[\begin{array}{cccccccc}\mathrm{B}_{5.3} & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0\end{array}\right]=$

$$
=\left[\begin{array}{c}
\mathrm{R}_{\mathrm{Y}_{\text {dom }}} \\
-0
\end{array}\right]
$$

In a second step the data on depleted raw materials which have become part of gross output (in the home country or abroad), are $l i n k \in d$ with the domestic $u s e \quad o f \quad g o o d s$ described in the preceding subsection: The linkage can be made by establishing relationships between the depleted quantities of raw materials and the quantities of raw materials used as economic goods for intermediate or final purposes:


$R^{*}(g$, dir) denotes the quantities of depleted raw materials which are $d i r e c t i y$ needed in the home country or in the rest of the world to deliver marketable raw materials as goods for intermediate or
final uses. The linkage between the use of depleted raw materials and their use as goods is obtained by introducing coefficient matrix $\mathrm{R}_{\mathrm{X}} \mathrm{g}^{\mathrm{g}}(\mathrm{g})$ :
(64) $\quad R_{X}^{g}(g)=\left[\begin{array}{l}R_{X_{\text {dom }}}(g) \\ -\mathrm{R}_{X_{\text {for }}}(g)\end{array}\right]=$

$$
=\left[\begin{array}{ll:ll} 
& & & \\
R_{X_{d o m}}^{g} & \left(g_{\text {dom }}\right) & R_{X_{X o m}}^{g}\left(g_{i m p}\right) \\
\hdashline R_{X_{\text {dor }}} & \left(g_{\text {dom }}\right) & R_{X_{f o r}}\left(g_{i m p}\right)
\end{array}\right]
$$

The coefficients described in (64) are normally larger than one, in exception al cases equad to one. For analyzing transboundary flows of raw materials, the possibility of $d i f f e r e n t$ coefficients for imported and d 0 m e t i c raw materials has been taken into account. Because of transportation losses, the coefficients of imported raw materials could be substantially higher than the coefficients of the raw materials of domestic origin. The row classification of $\mathrm{R}_{\mathrm{X}}{ }^{\mathrm{g}}(\mathrm{g})$ reflects the two classifications by type of raw materials in Table 1 , rows 5 and 6; the column classification of $R_{X}{ }^{g}(g)$ reflects the twofold product classification of Table 1 , rows 2 and 4.

The physical quantities of raw materials which are depleted and $i m m e d i a t e l y \quad c o n s u m e d$ as intermediate inputs are related to the monetary gross output of the branches:

$$
R_{x}^{q}(q)=\left[\begin{array}{ll}
R_{x_{d o m}} & (q)  \tag{65}\\
-R_{X_{f o r}} & (q)
\end{array}\right]
$$

Coefficient matrix $R_{X}{ }^{q}(q)$ has a row classification by type of raw materials and a column classification by branch.

The different types of coefficient matrices of raw materials [see equations (64) and (65)] could be used to link the goods models described in the last section with depletion of natural assets which is directly and indirectly required, in
thehome country as well as abroad, to produce the final products of a country. It is assumed again that the input structures for producing domestic and imported products are the same. The only differentiation refers to the coefficients of the quantities of depleted raw materials and to the raw materials used as goods:
(66) $\quad R_{Y}^{*}=\left(\left[\begin{array}{l}R_{X_{\text {dom }}}(q) \\ \hdashline R_{X_{\text {for }}}(q)\end{array}\right]+\right.$

$$
+\left[\begin{array}{ll}
{ }^{R_{X}} & g \\
\hdashline_{\text {dom }} & (g) \\
{ }^{R_{X_{f o r}}} & (g)
\end{array}\right] \cdot\left[\begin{array}{l}
G_{Y_{\text {dom }}} \\
\bar{G}_{\mathbf{Y}_{\text {imp }}}^{-}
\end{array}\right]+
$$

$$
+\left[\begin{array}{c}
\mathrm{R}_{\mathrm{Y}^{\text {dom }}} \\
- \hdashline 0
\end{array}\right]
$$

$$
\begin{aligned}
& +\left[\begin{array}{ll}
R_{X_{d o m}}^{g} & (g) \\
\hdashline R_{X_{f o r}} & (g)
\end{array}\right] \cdot\left[\begin{array}{c}
G_{X_{\text {dom }}} \\
-G_{X_{i m p}}
\end{array}\right], \quad . \\
& \text { - }\left[I-X^{q}\right]^{-1} y+
\end{aligned}
$$

A more detailed analysis of the use of raw materials is possible if (I-Xq) ${ }^{-1} Y$ is further subdivided. The use of raw materials of $d o m e s t i c o r i g i n$ is limited to the following matrix:


$$
\begin{aligned}
& \cdot\left[\begin{array}{c}
\mathrm{G}_{\mathrm{X}_{\text {dom }}}^{\mathrm{q}} \\
-0
\end{array}\right] \text {, } \\
& \text { - }\left[I-X_{d o m}^{q}\right]^{-1} Y_{d o m}+
\end{aligned}
$$

$$
\begin{aligned}
& {\left[\begin{array}{c}
\mathrm{G}_{\mathrm{Y}_{\text {dom }}} \\
-\mathrm{O} \\
0
\end{array}\right]}
\end{aligned}
$$

In the following equation, raw materials depleted in the $r e s t \quad 0 f t h e w o r l d$ and not imported but $d i r e c t l y \quad t r a n s p o r t e d$ by domestic economic units to the domestic country are described:
(68) $R_{Y}^{*}(f \circ r)=\left(\left[\begin{array}{c}0 \\ -R_{X_{f o r}}(q)\end{array}\right]+\left[\begin{array}{c}0 \\ -\mathrm{R}_{\mathrm{X}_{\text {for }}}(\mathrm{g})\end{array}\right]\right.$

$$
\left[\begin{array}{c}
G_{X_{d o m}}^{q} \\
-0
\end{array}\right], \quad\left[I-X_{d o m}^{q}\right]^{-1} Y_{d o m}+
$$

$$
+\left[\begin{array}{c}
0 \\
\bar{R}_{X_{f o r}}(g)
\end{array}\right] \cdot\left[\begin{array}{c}
G_{Y} \\
-\frac{d o m}{} \\
0
\end{array}\right]
$$

A third type of raw materials depleted in the rest of the world are $i m p o r t e d$ as goods without major modifications:


$$
\begin{aligned}
& { }^{\left[I-X_{d o m}^{q}\right]^{-1} Y_{\text {dom }}+} \\
& +\left[\begin{array}{ll}
R_{X_{\text {dom }}}^{g} & (g) \\
-R_{X_{\text {for }}} & (g)
\end{array}\right] \cdot\left[\begin{array}{c}
0 \\
\bar{G}_{Y_{i m p}}^{---}
\end{array}\right]
\end{aligned}
$$

Other raw materials have been used directly or indirectly to $p r o d u c e \quad i m p o r t e d$ products.

To link raw materials directly or indirectly required for the different $p r o d u c t \quad g r o u p s \quad o f$ final uses, the following matrix could be applied:
(70) $R_{Y}^{*}=\left[R_{Y}^{*}(n g) \quad \mid R_{Y}^{*}(g)\right]$
with


$$
\begin{aligned}
& \cdot\left[\begin{array}{ll}
G_{X_{d o m}} \\
-G_{X_{i m p}}
\end{array}\right], \\
& \cdot\left[I-x^{q}\right]^{-1} \hat{y}+ \\
& +\left[\begin{array}{l}
R_{X_{\text {dom }}}(g) \\
\bar{R}_{X_{\text {for }}}(g)
\end{array}\right] \cdot\left[\begin{array}{c}
g_{Y_{\text {dom }}} \\
\bar{g}_{Y_{\text {imp }}}
\end{array}\right]
\end{aligned}
$$

(72) $\mathrm{R}_{\mathrm{Y}}^{*}(\mathrm{ng})=r_{\mathbf{Y}_{\text {dom }}}$
$\mathrm{g}_{\mathrm{Y}_{\text {dom }}}$ and $\mathrm{I}_{\mathbf{Y}_{\text {imp }}}$ are defined in (56) and (57). $\mathrm{r}_{\mathbf{Y}_{\text {dom }}}$ is a similar column vector with the row totals of $\mathrm{R}_{\mathrm{Y}_{\text {dom }}}$ as elements:
(73) $r_{y_{\text {dom }}}=R_{y_{\text {dom }}} e$

### 2.3.3 Residuals models

The residual models presented in this section focus on how residual flows could be $\quad$ i $n k e d$ with production or consumption activities and on the extent to which domestic use of goods indirectly induces an output of residuals in the rest of the world. The quantities of residuals are taken into account even if they are treated or stored by environmental protection activities. This concept allows to compare the amount of residuals treated or stored by environmental protection activities, with the remaining residuals which enter the natural environment after being transformed or stored within environmental protection facilities. Residuals stored in controlled landfills are shown as "intermediate" inputs of branches
producing environmental protection services (column 1 of Table 1). This treatment facilitates an input-output analysis of the stored residuals. The description of the impacts of environmental protection activities has to be limited to the analysis of "end-of-pipe" technologies. The impacts of integrated environmental protection facilities could only be analysed by comparing different production and consumption processes. Some simple models which take into account such substitution activities are presented in section 2.5. Again, it should be emphasized that the matrices of residuals do not have to be complete with regard to type of residuals.

The $t \circ t$ a 1 out $p u t$ of residuals caused by domestic production or consumption activities comprises three components (see Table 1):
(74) $S_{X}=-\left[\begin{array}{lll}B_{8.1} & B_{8.2}\end{array}\right]-\left[\begin{array}{ll}0 & B_{12.2}\end{array}\right]$
(75) $\mathrm{S}_{\mathrm{Y}}=$
$=-\left[\begin{array}{llllllllll}B_{8.3} & 0 & B_{8.5} & B_{8.6} & B_{8.7} & B_{8.8} & 0 & 0 & \end{array}\right]-$
$-\left[\begin{array}{lllllllll}B_{12.3} & 0 & B_{12.5} & B_{12.6} & B_{12.7} & B_{12.8} & 0 & 0\end{array}\right]$
(76) $s_{\text {imp }}=s_{X_{i m p}}+s_{Y_{i m p}}=b_{9.11}+b_{13.11}$
$S_{X}$ denotes the total amount of residuals of production activities; $S_{Y}$ indicates the residuals connected with the final uses of products. Both matrices contain substances which are discharged into the natural environment (Table 1, row 8) and are further treated or stored (Table 1, row 12). The residuals are shifted from their origin with a negative sign (-) and to their destination with a positive sign (+). Therefore, the Belements defining $S_{X}$ and $S_{Y}$ in the equation (74) and (75) have a negative sign. For defining $S_{X}$ and $S_{Y}$ with positive elements, a change of signs was necessary. In
equation (76), residuals originating in the rest of the world and transported to the home country have been described. These materials have - with or without permission - been stored in uncontrolled landfills (bg.11) or have been imported for further treatment. In the latter case, the quantities of imported residuals shown in row 9 of Table 1 correspond with the monetary value of exported environmental protection services (see element $\mathrm{A}_{1} .10$ in Table 1).

The $t r e a t m e n t$ or $s t o r a g e \quad o f$ residuals comprises domestic treatment or storage of domestic ( $\mathrm{B}_{12} .1$ ) or imported ( $\mathrm{B}_{13} .1$ ) residuals, uncontrolled discharge into the natural environment of the rest of the world ( $\mathrm{B}_{8} .10$ ), and export of residuals for further treatment or storage in foreign environmental protection facilities ( $\mathrm{B}_{12} .10$ ):

$$
\begin{align*}
W_{X} & =W_{X_{d o m}}+W_{X_{\text {imp }}}=  \tag{77}\\
& =\left[\begin{array}{llllll}
B_{12.1} & 0 & ]+\left[{ }_{13.1}\right. & 0 & ] \\
W_{Y_{d o m}} & =\left[\begin{array}{llllllll}
0 & 0 & 0 & 0 & 0 & 0 & 0 & B_{8.10}
\end{array}\right]+ \\
& +\left[\begin{array}{llllllll}
0 & 0 & 0 & 0 & 0 & 0 & 0 & B_{12.10}
\end{array}\right]
\end{array} .\right.
\end{align*}
$$

The residuals $d i s c h a r g e d$ into the domestic natural environment (Table 1, B8.9 and B9.9) can be calculated as the difference between the total amount of residuals and the residuals treated or stored:
(79) $s-W=S_{X} e+S_{Y} e+s_{i m p}-W_{X} e-W_{Y} e$
with e $=$ unit vector.

A $\quad 1 \mathrm{ink}$ a g e of the output of residuals with the g o o d s m o dels described could be achieved
again by using coefficient matrices which relate the residuals, first, with the monetary data on gross output or, second, with the physical quantities of goods used. In the first case, residuals linked with the production of specific products have to be identified. In the second case, residuals caused by the consumption of certain goods have to be determined (e.g. residuals of energy consumption). In linking residuals with quantities of goods, a further disaggregation of the use of physical quantities of goods with regard to specific types of use seems to be necessary because the type and amount of residuals depend heavily on the specific use of the goods causing the residuals.

The residuals of production activities could be the result of a transformation process of residuals treated in environmental protection facilities (W). They are included in Table 1 as part of B8.1. Other residuals can be related to the monetary output of the respective branch or with physical inputs of goods in the following way:


The residuals caused by final uses are:

$S_{Y}(n g)$ contains the residuals which originate in the withdrawal of produced assets and the transition of
residuals stored in controlled landfill in the natural environment (Table 1: B8.5 to $\mathrm{B}_{8} .8$ and $\mathrm{B}_{12.5}$ to $\mathrm{B}_{12} .8$ ).

The amount of residuals which are treated or stored ( $B_{12.1}$ and $B_{13.1}$ ) could be related to the monetary value of gross output of the different environmental protection services:

$$
\begin{equation*}
w_{x}=\left[w_{x_{\text {dom }}}^{q}+w_{x_{i m p}}^{q}\right] \hat{q} \tag{82}
\end{equation*}
$$

with
(83) $\mathrm{W}_{\mathrm{X}_{\mathrm{dom}}}^{\mathrm{q}}=\left[\mathrm{B}_{12.1} 0\right] \hat{\mathrm{q}}^{-1}$
(84) $\mathrm{W}_{\mathrm{X}_{\mathrm{imp}}}^{\mathrm{q}}=\left[\mathrm{B}_{13.1} 0\right] \hat{\mathrm{q}}^{-1}$

In (83) and (84), treated or stored residuals are subdivided with respect to their origin from domestic activities or from the rest of the world.

It is assumed that residuals stored in a controlled landfill do not cause a further burden on the natural environment immediately after storage. On the other hand, residuals treated in environmental protection facilities will createother residuals which, as long as they are not stored, burden the natural environment. It is, therefore, necessary to treat the transformation of residuals within environmental protection facilities explicitly:
(85) $S_{X}(w)=S_{X}{ }_{X}(w)\left[W_{X_{d o m}}^{q}(\right.$ ext $)+W_{X_{i m p}}^{q}($ ext $\left.)\right] \hat{q}$
$S^{W}{ }_{X(w)}$ denotes a coefficient matrix which is classified in rows by type of residuals and in columns by type of treated or stored residuals. To analyze the impact of
the different types of environmental protection measures on the amount of remaining residuals, the row classification of coefficient matrices ${ }^{W_{X_{d o m}}}{ }^{q}$ and $\mathrm{W}_{X_{\text {imp }}}{ }^{q}$ and the column classification of matrix $\mathrm{S}^{\mathrm{W}} \mathrm{X}(\mathrm{w})$ can be further disaggregated by type of storage and of environmental protection measure, respectively.

In a next step, the coefficient matrices can be $1 \mathrm{i} n k e d$ with the described $g \circ \circ d \mathrm{~s}$ $\mathrm{m} \circ \mathrm{dels}$. . If the input structures of domestic and imported products are the same, and if the residual coefficients could also be used for analyzing domestic as well as imported products, the total amount of residuals caused by domestic final uses of products in the home country as well as in the rest of the world can be calculated by using equation (86):
(86) $(S-W)_{Y}^{*}=$

$$
\begin{aligned}
& +S_{X(w)}^{w}\left[W_{X_{d o m}}^{q}(\text { ext })+W_{X_{i m p}}^{q}(\text { ext })\right]- \\
& -\left[w_{x_{\text {dom }}}^{q}+w_{x_{i m p}}^{q}\right], \cdot \\
& \text { - }\left[I-X^{q}\right]^{-1} Y+
\end{aligned}
$$

The residuals burdening the domestic natural environment comprise the following elements:
(87) $(\mathrm{s}-\mathrm{W})_{\mathrm{Y}}^{*}($ dom $)=$

$$
\begin{aligned}
& +S_{X(w)}^{w}\left[w_{X_{\text {dom }}}^{q}(\text { ext })+w_{X_{\text {imp }}}^{q}(\text { ext })\right]- \\
& \left.-\left[w_{X_{d o m}}^{q}+w_{X_{i m p}}^{q}\right]\right) \cdot \\
& \text { - }\left[\mathrm{I}-\mathrm{X}_{\mathrm{dom}}^{\mathrm{q}}\right]^{-1} \mathrm{y}_{\mathrm{dom}}+
\end{aligned}
$$

This amount is still raised by the "imported" residuals, ${ }^{\mathbf{S}} \mathrm{X}_{\text {imp }}$ and ${ }^{\mathbf{5}} \mathbf{Y}_{\text {imp }}$ (see equation (76)).

If residuals are not related to the categories of final uses but to the different $g r o u p s o f$ final products, the following equation could be used:
(88) $(S-W)_{Y}^{*}=$

$$
=\left[\begin{array}{l:l}
(s-w)_{Y}^{*}(n g) & (s-w)_{Y}^{*}(g)
\end{array}\right]
$$

with

$$
\begin{aligned}
& \text { (89) }(S-W)_{Y}^{*}(g)=\left(S_{X}{ }_{(q)}^{q}+S_{X}{ }_{(G)}^{g}\right.
\end{aligned}
$$

$$
\begin{aligned}
& -\left[W_{x_{d o m}}^{q}+W_{x_{i m p}}^{q}\right], \quad\left[I-x^{q}\right]^{-1} \hat{y}+ \\
& +S_{Y(g)}^{g}\left[\begin{array}{c}
g_{Y_{\text {dom }}}(\text { ext }) \\
\bar{g}_{Y_{\text {imp }}}^{\left.-\overline{e x x}^{\prime}\right)}
\end{array}\right] \\
& \text { and } \\
& (90)(S-W)_{Y}^{*}(n g)=s_{Y_{\text {dom }}}+s_{X_{i m p}}+s_{Y_{i m p}}-w_{\mathbf{Y}_{\text {dom }}} \\
& g_{Y_{\text {dom }}}, g_{Y_{\text {imp }}}, s_{Y_{\text {dom }}} \text { and }{ }^{W_{Y_{\text {dom }}}} \text { are column vectors which } \\
& \text { represent row sums of the following matrices: }
\end{aligned}
$$

(91) $g_{Y_{\text {dom }}}($ ext $)=G_{Y_{\text {dom }}}($ ext $) e$
(92) $g_{Y_{\text {imp }}}($ ext $)=G_{Y_{i m p}}($ ext $) e$
(93) $\mathbf{s}_{\mathbf{Y}_{\text {dom }}}=\mathbf{S}_{\mathbf{Y}_{\text {dom }}} \mathbf{e}$
(94) $W_{Y_{\text {dom }}}=W_{Y_{\text {dom }}} e$

The extensions of matrices $\mathrm{Gy}_{\mathrm{y}}$ denoted in (91) and (92) with (ext) refer to a disaggregation by type of use.

## 2．4 Inpu：－ธこここここ analysis of imputed envizor＝er．こai costs

Using inぼニーーごこput models，indirect impu：e m environmental costs of producing or consuming products can be identified． The analysis is based on imputed environmental costs at maintenarse vaiues．Such calculation could be used to analyse dowestic as well as international
interreiaここonships．The models presented in this section aze simple examples which illustrate the possibi之iこうes of input－output analysis（see also Blazefczax，Edier，1991）．Again，completeness of the categories $\quad=$ environmental costs is not necessary．

Imputed environmental costs of depleting and degrading the domes：ic or foreign natural environment by domestic economic activities comprise－according to Table 1 － the folicining items：
（95）$K_{X}=$
$\left[\begin{array}{cc}c_{5.1} & c_{5.2} \\ c_{6.1} & c_{6.2} \\ c_{7.1} & c_{7.2} \\ c_{8.1} & c_{8.2} \\ 0 & 0 \\ c_{11.1} & c_{11.2}\end{array}\right]$
and
（96） $\mathrm{R}_{\mathrm{Y}}=\mathrm{K}_{\mathrm{Y}_{\text {dom }}}=$
$=\left[\begin{array}{cccccc}\mathrm{C}_{5} .3 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 \\ \mathrm{C}_{7} .3 & 0 & 0 & 0 & 0 & 0 \\ \mathrm{C}_{8.3} & 0 & 0 & 0 & 0 & 0 \\ 0 & -\mathrm{C}_{10.4} & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0\end{array}\right]$

Matrices $K_{X}$ and $K_{Y}$ denote imputed environmental costs caused by production activities ( $\mathrm{K}_{\mathrm{X}}$ ) or by final consumption activities ( $\mathrm{K}_{\mathrm{Y}}$ ). Final consumption activities of households ( $\mathrm{C}_{5} .3, \mathrm{C}_{7} .3$ and $\mathrm{C}_{8} .3$ ) cause an additional burden on the natural environment; restoration activities of government or non-profit organizations alleviate this burden ( $\mathrm{C}_{10}$.4).

Environmental costs caused by production activities can be related to grossoutput of the branches:
(97) $K_{X}^{q}=K_{X} \hat{q}^{-1}$

Using this coefficient matrix, imputed environmental costs directly and indirectly caused by the fin i 1 uses of products can be calculated:

$$
\begin{equation*}
K_{d o m}^{*}=K_{X}^{G}\left[I-X_{d o m}^{q}\right]^{-1} \cdot Y_{d o m}+K_{Y_{d o m}} \tag{98}
\end{equation*}
$$

Matrix $K^{*}$ dom is classified in rows by type of environmental costs and in columns by category of final uses.
$K^{*}$ dom is limited to environmental costs caused in the home country. The model can be extended by taking into account the environmental costs in the restof th e world indirectly induced by importing products for domestic uses.

If the relations of imputed environmental costs and intermediate inputs of products to gross output are the same for domestic and imported products, the total environmental costs can be calculated by the following equation:
（99）$\quad K^{*}=K_{X}^{q}\left(I-X_{d o m}^{q}\right)^{-1} Y_{d o m}+$

$$
\begin{aligned}
& +K_{X}^{q}\left(I-X^{q}\right)^{-1} X_{i m p}^{q} \\
& \cdot\left(I-X_{d o m}^{q}\right)^{-1} Y_{d o m}+ \\
& +K_{X}^{q}\left(I-X^{q}\right)^{-1} Y_{i m p}+K_{Y}
\end{aligned}
$$

The four terms of the right side of the equation（99） indicate domestic environmental costs of production， foreign environmental costs directly or indirectly caused by the imported intermediate and final products， and domestic environmental costs caused by final consumption activities．

It might ie interesting to develop a comprehensive bala ：$=$ e of foreigntrade with
 This caンニンショ＝ion requires a separation of the exports：

$Y_{\text {dom，ex }} \div-=こ=$ こes domestic products exported，$Y_{\text {imp，}}$ exp imporeeさ こここここここs ze－exported without touching the


Imputez $\because \because \because 乙=$ こェe：＝al costs caused directly or indireここ $\because=\because \quad$ ́ports of products are
(102) $K_{\exp }^{*}=K_{X}^{q}\left(I-X_{d o m}^{q}\right)^{-1}$.

$$
\begin{aligned}
& \text { - } Y_{\text {dom, }} \exp ^{+} \\
& +K_{X}^{q}\left(I-X^{q}\right)^{-1} X_{i m p}^{q}\left(I-X_{d o m}^{q}\right)^{-1} . \\
& \text { - } Y_{\text {dom, }} \exp +K_{X}^{q}\left(I-X^{q}\right)^{-1} Y_{i m p}, \exp
\end{aligned}
$$

I mports of products have directly or indirectly caused the following imputed environmental costs:
(103) $K_{i m p}^{*}=K_{X}^{q}\left(I-X^{q}\right)^{-1}$.

$$
\begin{aligned}
& \cdot X_{i m p}^{q}\left(I-X_{d o m}^{q}\right)^{-1} Y_{d o m}+ \\
& +X_{X}^{q}\left(I-X^{q}\right)^{-1} Y_{i m p}
\end{aligned}
$$

 caused by exports and by imports could be calculated in the following manner:
$K_{\text {exp }}^{*}-K_{i m p}^{*}=$
$=\mathrm{K}_{\mathrm{X}}^{\mathrm{q}}\left(\mathrm{I}-\mathrm{X}_{\mathrm{dom}}^{\mathrm{q}}\right)^{-1} \mathrm{Y}_{\mathrm{dom}, \exp }-$
$-K_{X}^{q}\left(I-X^{q}\right)^{-1} X_{i m p}^{q}\left(I-X_{d o m}^{q}\right)^{-1}$.

- $\left(Y_{\text {dom }}-Y_{\text {dom,exp }}\right)$ -
$-K_{x}^{q}\left(I-X^{q}\right)^{-1}\left(Y_{i m p}-Y_{i m p, e x p}\right)$

The first term on the right side of (104) denotes imputed environmental costs directly or indirectly caused by producing export products in the home country. The second term comprises environmental costs caused by production of imported intermediate products in the rest of the world as long as these intermediate products are not used for producing export products. The third term describes environmental costs in the
rest of the world caused by producing imported final products as long as they are not re－exported．

It has to be mentioned that the environmental balance of foreign trade could contain some double counting because imported products could have been produced in the rest of the world by using exported products．Furthermore，the model could be improved by introducing specific input structures and specific relationships of imputed environmental costs to gross output for countries producing imported products．

## 2．5 Input－output analysis of the impacts of activities for maintaining natural assets

Imputed environmental costs shown in the extended input－output table comprise costs of hypothetical activities which would have been required to maintain the quantitative and qualitative level of natural assets．These activities would have led to changes of the input structures of production and to a modified level and structure of $f$ inal products．

The input－output models presented in this section describe the $i m m e d i a t e i m p a c t s \quad o n$ the physical ard monetary data describing production and use of products．In a first step，these immediate impacts are treated as exogenous changes of the data used in she input－output model．In a second step，the $i n \in i r e c t e f f e c t s$ on the use of raw materials and cr the output of residuals are analysed within an inp：こ－cu＝put model．The structure of the models is very simpie and uses the usual assumptions of comparative sこaこここ ：－nput－output analysis．Of course， these modeis $c=0 i d$ be replaced by more complicated

preliminary rough impression of the impacts of maintenance activities, the given models may be sufficient.

The following considerations are limited to the case of preventing an environmental burden caused by residuals. Possible immediate impacts of the different types of avoidance activities on the monetary and physical input coefficients ( $X{ }^{q}$ and $\mathrm{GX}_{\mathrm{X}}{ }^{\mathrm{q}}$ ) as well as on the monetary and physical data of final uses ( $Y$ and $G y$ ) are shown in Table 3. The following comments on possible cases described in the table are given by referring to the rows and columns of this table, e.g. (1.3) denotes the first row and third column.
(1.1) A reduction of production activities immediately leads to a decrease in the intermediate and final uses of the respective products. This implies a lessening of the monetary values of $X \mathcal{I}$ and $Y$ as well as of the physical goods quantities of $\mathrm{G}_{\mathrm{X}}{ }^{\mathrm{q}}$ and Gy. Possible input-output models based on these modified input-output data could show the direct and indirect impacts on users of the products without taking into account the possibilities of substitution. If the reaction of users should be analysed too, one (or a combination) of the types of immediate impacts described in rows 2 and 3 of Table 3 could be used as starting point for further analysis.
(1.3) A reduction of household consumption activities implies a decrease in the monetary and physical value of final uses ( $Y$ and $G_{Y}$ ) without immediate changes of input coefficients $X^{q}$ and $G_{X}{ }^{q}$. If the reduction of specific household consumption activities is accompanied by a complete or partial substitution, case (2.3) can be applied.

Table 3: I-sodiate impacta of activities of maintaining the natural assets on production and use of products

|  | Discharge of residuals into the natural environment |  |  |  |
| :---: | :---: | :---: | :---: | :---: |
|  | of production activities |  |  | of consumption activities of households |
|  | $\begin{aligned} & \text { cur } \\ & \text { prod } \end{aligned}$ |  | use of produced fixed assets |  |
|  | (1) |  | (2) | (3) |
| 1. Reduction of economic activities | $\begin{aligned} & \Delta x^{q} \\ & (-) \\ & \Delta G \mathcal{X} \\ & (-) \end{aligned}$ | $\begin{aligned} & \Delta Y \\ & (-) \\ & \Delta G_{Y} \\ & (-) \end{aligned}$ |  | $\begin{aligned} & \Delta Y \\ & (-) \\ & \Delta G Y \\ & (-) \end{aligned}$ |
| 2. Substitution of economic activities (new products etc.) (output substitution) | $\begin{aligned} & \Delta X^{q} \\ & (+,-) \\ & \Delta G_{X}^{q} \\ & (+,-) \end{aligned}$ | $\begin{aligned} & \Delta Y \\ & (+,-) \\ & \Delta G_{Y} \\ & (+,-) \end{aligned}$ |  | $\begin{aligned} & \Delta Y \\ & (+,-) \\ & \Delta G_{Y} \\ & (+,-) \end{aligned}$ |
| 3. Changes of the etructure of products used for economic activities (input substitution) | $\begin{aligned} & \Delta X^{q} \\ & (+,-) \\ & \Delta G_{X}^{q} \\ & (+,-) \end{aligned}$ |  | $\begin{aligned} & \Delta Y \\ & (+,-) \\ & \Delta G_{Y} \\ & (+,-) \end{aligned}$ | $\begin{aligned} & \Delta Y \\ & (+,-) \\ & \Delta G_{Y} \\ & (+,-) \end{aligned}$ |
| 4. Avoidance of impacts of economic activities on the natural environment (end-of-pipe technologies etc.) | $\begin{aligned} & \Delta X^{q} \\ & (+) \\ & \Delta G_{X}^{q} \\ & (+) \end{aligned}$ | $\begin{aligned} & \Delta Y \\ & (+) \end{aligned}$ | $\Delta Y$ <br> (+) | $\Delta Y$ <br> (+) <br> ${ }_{\Delta} G_{Y}$ <br> (+) |
| 5. Activities for restoring or diminishing the impects of economic activities on the natural environment | $\begin{aligned} & \Delta X^{q} \\ & (+) \\ & \Delta G_{X}^{q} \\ & (+) \end{aligned}$ | $\begin{aligned} & \Delta Y \\ & (+) \end{aligned}$ |  | $\begin{aligned} & \Delta Y \\ & (+) \\ & \Delta G_{Y} \\ & (+) \end{aligned}$ |

## Explanations:

$\Delta X^{q} \quad$ positive or negative changes of the monetary input coefficients
$(+,-)$
$\Delta G_{X}^{q}$
$(+,-)$
$\Delta Y$
$(+,-) \quad$ positive or negative changes of the physical input coefficients
$\Delta G_{Y}$
$(+,-)$
(2.1) If the composition of the produced products has changed to more environmentally friendly products, the input structures will change as well as the structure of final uses. Thus, $X G, Y$, $G_{X}{ }^{q}$ and $G_{Y}$ is affected.
(2.3) In the case of substituting household consumption activities, immediate impacts refer to the monetary and physical data on final uses (Y and $\mathrm{G}_{\mathrm{Y}}$ ).
(3.1) If the input structures are modified without producing another product, only the input structures ( $X^{q}$ and $\mathrm{G}_{\mathrm{X}}{ }^{q}$ ) are immediately affected.
(3.2) Changing structures of the produced assets used in production will lead to new data on the capital formation of these assets (part of $Y$ and Gy).
(3.3) If the structure of products used for certain household consumption activities changes, immediate impacts on final uses $Y$ and $G y$ can be observed.
(4.1) Environmental protection activities which avoid
(4.2) the discharge of residuals of production
(5.1) activities into the natural environment, or which restore natural assets already affected, imply an increase of inputs of environmental protection activities. If environmental protection activities are part of non-market production, collective consumption (part of $Y$ ) will increase too. If the increase of environmental costs is completely or partly compensated by a reduction of other costs or by changes of the composition of products, the analysis of impacts could use combinations (2.1) or (3.1).
(4.3) Environmental protection activities of households
(5.3) that avoid or restore a deterioration of environmental quality by residuals, lead to an additional final demand. The corresponding data of matrices $Y$ and $G_{Y}$ will increase. If this increase is partly compensated by substitution measures, combinations (2.3) or (3.3) could be applied.

These immediate exogenously determined impacts of maintenance activities on the structure of intermediate inputs and on the level and structure of final uses could be used as a starting point for further a $n$ a $1 \mathrm{ys} \mathrm{i} s$ of the impacts of these exogenous changes on the level of production as well as on the depletion of natural assets and the level of residuals connected with the economic activitie;. The exogenous changes of the input-output are denoted in the following manner:
(105) $Y(\mathrm{~m})=Y+\mathbb{Y}=$
$=Y_{\text {dom }}+\Delta Y_{\text {dom }}+$
$+\mathbf{Y}_{\mathrm{imp}}+\Delta \mathrm{Y}_{\mathrm{imp}}$
$(106) G_{Y}(m)=G_{Y}+\Delta G_{Y}=$
(107) $x^{q}(m)=x^{q}+\Delta x^{q}=$

$$
\begin{aligned}
& =x_{d o m}^{q}+\Delta x_{d o m}^{q}+ \\
& +x_{i m p}^{q}+\Delta x_{i m p}^{q}
\end{aligned}
$$

(108) $\mathrm{G}_{\mathrm{X}}^{\mathrm{Q}}(\mathrm{m})=\mathrm{G}_{\mathrm{X}}^{\mathrm{q}}+\Delta \mathrm{G}_{\mathrm{X}}^{\mathrm{Q}}=$

The impacts on the physical and monetary data on production in the home country and in the $r e s t$ of th h world could be calculated with the following equations:
(109) $Q_{Y}^{*}(m)=\left[I-X^{q}(m)\right]^{-1}$.

$$
\begin{aligned}
& \cdot Y_{\text {dom }}(m)+ \\
& +\left[I-x^{q}(m)\right]^{-1} x_{i m p}^{q}(m) \cdot \\
& \cdot\left[I-x_{d o m}^{q}(m)\right]^{-1} Y_{d o m}(m)+ \\
& +\left[I-x^{q}(m)\right]^{-1} Y_{i m p}(m)
\end{aligned}
$$

$(110) G_{Y}^{*}(m)=G_{X}^{q}(m) \cdot$

$$
\begin{aligned}
& {\left[I-X^{q}(m)\right]^{-1} Y_{d o m}(m)+} \\
+ & G_{X}^{q}(m)\left[I-X^{q}(m)\right]^{-1} X_{i m p}^{q}(m) \\
\cdot & {\left[I-X_{d o m}^{q}(m)\right]^{-1} Y_{d o m}(m)+} \\
- & G_{X}^{q}(m)\left[I-X^{q}(m)\right]^{-1} Y_{i m p}(m)+ \\
+ & G_{Y}(m)
\end{aligned}
$$

The impacts on the level and structure of $r a w$ mater:ais are
(111) $R_{Y}^{*}(m)=R_{X}^{q}(q)+$

$$
\begin{aligned}
& \left.-R_{X}^{g}(g) G_{X}^{q}(m)\right] \cdot\left[I-X^{q}(m)\right]^{-1} \cdot \\
& \cdot Y(m)+R_{X}^{g}(g) G_{Y}(m)+R_{Y}(m)
\end{aligned}
$$

In addition, changes of the raw materials immediately depleted by households have to be taken into account: (112) $R_{Y}(m)=R_{Y}+\Delta R_{Y}$

The impacts on the $r e s i d u a l s$ could be compiled by using a modification of equation (86):

$$
\begin{aligned}
& (113)(S-W)_{Y}^{*}(m)=\left[S_{X(q)}^{q}+\right. \\
& +S_{X(g)}^{g} G_{X}^{q}(\text { ext, } m)+S_{X(w)}^{W} . \\
& \text { - } \left.W_{X}^{q}(e x t)-W_{X}^{q}\right]\left[I-X^{q}(m)\right]^{-1} \text {. } \\
& \cdot Y(m)+\left[S_{Y}(n g)+S_{Y(g)}^{g} .\right. \\
& \text { - } \left.G_{Y}(\text { ext, } m)-W_{Y_{d o m}}\right]
\end{aligned}
$$

Equation (113) implies that the matrices of extended input structures of $g \circ \circ d s \quad f 10 w s$ and extended final uses of goods also have to be modified:
$(114) G_{X}^{q}(e x t, m)=G_{X}^{q}(e x t)+\Delta G_{X}^{q}(e x t)$
(115) $G_{Y}($ ext, $m)=G_{Y}(e x t)+\Delta G_{Y}($ ext $)$

As far as the activities to avoid environmental deterioration by residuals have impacts on the residual coefficients, modified coefficient matrices

$$
s_{X(q)}^{q}, \quad s_{X(g)}^{g}, \quad s_{X(w)}^{W} \quad \text { and } \quad S_{Y(g)}^{g}
$$

have to be taken into account in equation (113).

## List of abbreviations used

```
1. Matrices and vectors
    Capital letters: matrices
    Small letters: vectors
A, a Monetary elements of the traditional input-
        output table
B, b Physical elements of the extended input-output
        table
C, C Additional monetary elements of the extended
        input-output table
e Unit vector
G,g Use of goods (in physical terms)
I Identity matrix
K Additional imputed costs of depleting natural
        assets and degrading environmental media by
        residuals
    Q.q Gross output (in monetary terms)
    R, r Raw materials (in physical terms)
    S, s Residuals (in physical terms)
    S - W Discharge of residuals into the natural
    environment
U, u Environmental protection activities
```

| W, w | Residuals, economically treated or stored |
| :---: | :---: |
| $\mathrm{X}, \mathrm{x}$ | Intermediate consumption (in monetary terms) |
| Y, Y | Final uses of products (in monetary terms) |
| Z, z | Gross value added (in monetary terms) |
| 2. Exp | atory indices of the matrices and vectors |
| dir | Direct |
| dom | Domestic production |
| exp | Export |
| ext | Extended row or column classification |
| for | Direct depletion in the rest of the world |
| g | Superscript: coefficients related to the (physical) use of products |
| (g) | Proportion depending on the amount of the (physical) consumption of products |
| i | Current number of rows in Table 1 |
| imp | Imported |
| indir | Indirect |
| j | Current number of columns in Table 1 |
| (m) | Modified within the scope of the impact analysis of maintaining the natural assets |


| ( ng ) | Proportion not depending on the amount of the (physical) consumption of products |
| :---: | :---: |
| (nu) | Not connected with environmental protection activities |
| ( n W) | Not depending on the amount of treated or stored residuals |
| q | Superscript: coefficients related to the (monetary) gross output |
| (q) | Proportion depending on the amount of the (monetary) gross output |
| (u) | Connected with environmental protection activities |
| W | Superscript: coefficients related to the treated or stored residuals |
| (w) | Proportion depending on the amount of treated or stored residuals |
| * | Direct and indirect attachment to the categories of final uses |
| $\Delta$ | Change |
| $\wedge$ | Diagonal matrix |
| , | Superscript: transposed column vector |
| -1 | Inverse |

3. Reference lists of matrices and vectors used (in brackets: number of equation)

| $\mathbf{A}_{\text {i. }} \mathrm{j}$ | Table 1 | $\Delta \mathrm{G}_{\mathrm{X}_{\text {dom }}}^{\mathrm{q}}$ | (108) |
| :---: | :---: | :---: | :---: |
| $\mathrm{a}_{\text {i. }}{ }^{\text {d }}$ | Table 1 | $\Delta G_{x_{i m p}}^{q}$ | (108) |
| $B_{i . j}$ | Table 1 | $\Delta \mathrm{G}_{\mathrm{X}}^{\mathrm{q}}$ (ext,m) | (114) |
| $\mathrm{b}_{\text {i.j }}$ | Table 1 | - - - - - | - - - |
| $C_{i . j}$ | Table 1 | $\mathrm{G}_{\mathrm{Y}}$ | (52) |
| $c_{i . j}$ | Table 1 | $\mathrm{G}_{\mathbf{Y}_{\text {dom }}}$ | (52) |
| e | before (9) | $\mathrm{g}_{\mathrm{Y}_{\text {dom }}}$ | (56) |
| $\mathrm{G}_{\mathrm{X}}$ | (50) | $\mathrm{G}_{\mathrm{Y}_{\text {imp }}}$ | (52) |
| $\mathrm{G}_{\mathrm{X}_{\text {dom }}}$ | (50) | $\mathrm{g}_{\mathrm{Y}_{\text {imp }}}$ | (57) |
| $\mathrm{G}_{\mathrm{X}_{\text {imp }}}$ | (50) | $\mathrm{G}_{\mathrm{Y}_{\text {dom }}}$ (ext) | (81) |
| $\mathrm{G}_{\mathrm{X}}^{\mathrm{q}}$ | (51) | $\mathrm{g}_{\mathrm{Y}_{\text {dom }}}$ (ext) | (91) |
| $G_{x_{\text {dom }}}^{q}$ | (51) | $\mathrm{G}_{\mathrm{Y}_{\text {imp }}}$ (ext) | (81) |
| $\mathrm{G}_{\mathrm{X}}{ }^{\text {q }}$ | (51) | $g_{Y_{i m p}}(e x t)$ | (92) |
| imp |  | $\mathrm{G}_{\mathbf{Y}}(\mathrm{m})$ | (106) |
| $G_{x_{\text {dom }}}^{q}(e x t)$ | (80) | $\mathrm{G}_{\mathrm{Y}}(\mathrm{ext}, \mathrm{m})$ | (115) |
| $G_{x_{i m p}}^{q}(e x t)$ | (80) | $\Delta G_{Y}$ | (106) |
| $\mathrm{G}_{\mathrm{X}}^{\mathrm{q}}(\mathrm{m})$ | (108) | A $\mathrm{G}_{\mathrm{I}_{\text {dom }}}$ | (106) |
| $\mathrm{G}_{\mathrm{X}}^{\mathrm{q}}(\mathrm{ext}, \mathrm{m})$ | (114) | $\Delta G_{Y_{i m p}}$ | (106) |
|  |  | $\Delta \mathrm{G}_{\mathrm{Y}}($ ext $)$ | (115) |
| $\Delta G_{X}^{q}$ | (108) | - - - - - | - - - |
|  |  | $\mathrm{G}_{\mathrm{Y}}$ | (53) |


| $\mathrm{G}_{\mathrm{Y}}^{*}(\mathrm{~m})$ | (110) | $\mathrm{R}_{\mathrm{X}}$ ( g$)$ | (60) |
| :---: | :---: | :---: | :---: |
|  |  |  |  |
|  |  | $\mathrm{R}_{\mathrm{X}_{\text {dom }}}$ | (58) |
| $\mathrm{G}_{\mathbf{Y}}^{*}$ | (55) | ${ }^{R_{x_{\text {dom }}}}(q)$ | (59) |
|  |  |  |  |
| I | before (9) | $\mathrm{R}_{\mathrm{X}_{\text {dom }}}(\mathrm{g})$ | (60) |
| $\mathrm{K}_{\mathrm{X}}$ | (95) | $\mathrm{R}_{\mathrm{X}_{\text {for }}}$ | (58) |
| $\mathrm{K}_{\mathrm{X}}^{\mathrm{q}}$ | (97) | $\mathrm{R}_{\mathrm{X}}$ ( $\mathrm{q}^{\text {) }}$ | (59) |
| $\mathrm{K}_{\mathrm{Y}}$ | (96) | $\mathrm{R}_{\mathrm{X}_{\text {for }}}(\mathrm{g})$ | (60) |
| $\mathrm{K}_{\mathbf{Y}_{\text {dom }}}$ | (96) | $R_{X}^{\mathrm{g}}$ ( g$)$ | (64) |
| K* | (99) | $\mathrm{R}_{\mathrm{X}_{\text {dom }}}^{\mathrm{g}}$ (g) | (63) |
| $\mathrm{K}_{\text {dom }}^{*}$ | (98) | $\mathrm{R}_{\mathrm{X}_{\mathrm{for}}}^{\mathrm{g}}$ (g) | (63) |
| $\mathrm{K}_{\text {exp }}$ | (102) | $\mathrm{R}_{\mathrm{X}_{\text {dom }}}^{\mathrm{g}}$ ( $\left.\mathrm{g}_{\text {dom }}\right)$ | (64) |
| $\mathrm{K}_{\text {imp }}^{*}$ | (103) | $\mathrm{R}_{\mathrm{X}_{\text {dom }}}^{\mathrm{g}}$ ( $\left.\mathrm{g}_{\text {imp }}\right)$ | (64) |
| q | (6) |  |  |
|  |  | $\mathrm{R}_{\mathrm{X}_{\text {for }}}^{\mathrm{g}}$ ( $\left.\mathrm{g}_{\text {dom }}\right)$ | (64) |
| $Q_{Y}^{*}$ | (30) |  |  |
| 0 * | (31) | $\mathrm{R}_{\mathrm{X}_{\text {for }}}^{\mathrm{g}}$ ( $\mathrm{g}_{\text {imp }}$ ) | (64) |
| $Q_{Y}^{*}$ (dom) | (22) | $\mathrm{R}_{\mathrm{X}}^{\mathrm{q}}(\mathrm{q})$ | (65) |
| $Q_{\mathrm{y}}^{*}$ (dom) | (23) | $\mathrm{R}_{\mathrm{X}_{\text {dom }}}^{\mathrm{q}}$ (q) | (65) |
| $Q_{Y}^{*}(\mathrm{~m})$ | (109) | $\mathrm{R}_{\mathrm{X}_{\text {for }}}^{\mathrm{q}}$ (q) | (65) |
| $\mathrm{R}_{\mathrm{X}}$ | (58) | $\mathrm{R}_{\mathbf{Y}}$ | (62) |
| $\mathrm{R}_{\mathrm{X}}$ (q) | (59) | $\mathrm{R}_{\mathrm{Y}_{\text {dom }}}$ | (62) |


| ${ }^{r^{\prime}}{ }_{\text {dom }}$ | (73) | $S_{Y}$ | (75) |
| :---: | :---: | :---: | :---: |
| $\mathrm{R}_{\mathrm{Y}}(\mathrm{m})$ | (112) | ${ }^{\mathbf{s}} \mathbf{Y}_{\text {dom }}$ | (93) |
| - $\mathrm{R}_{\mathrm{Y}}$ | (112) |  |  |
| - - - - - | - - - | ${ }^{\mathbf{s}} \mathbf{y}_{\text {imp }}$ | (76) |
| $\mathrm{R}^{*}$ ( $\mathrm{g}, \mathrm{dir}$ ) | (63) | $S_{Y_{\text {dom }}}(n g)$ | (81) |
| $\mathrm{R}_{\mathrm{Y}}^{*}$ | (66) | $S_{Y}{ }_{(g)}^{g}$ | (81) |
| $\mathrm{R}_{\mathrm{Y}}^{*}(\operatorname{dom})$ | (67) | $(S-W)_{Y}^{*}$ | (86) |
| $\mathrm{R}_{\mathrm{Y}}^{*}$ ( for ) | (68) | $(S-W)_{Y}^{*}(m)$ | (113) |
| $\mathrm{R}_{\mathrm{Y}}^{*}$ (imp, dir) | (69) | $(S-W)_{Y}^{*}$ (dom) | (87) |
| $\mathrm{R}_{\mathrm{Y}}^{*}(\mathrm{~m})$ | (111) | $(S-W)_{Y}^{*}$ | (88) |
| $\mathrm{R}_{\mathrm{Y}}{ }^{\text {r }}$ | (70) | $(S-W)_{Y}^{*}(g)$ | (89) |
| $\mathrm{R}_{\mathrm{Y}}^{*}$ (g) | (71) | $(S-W)_{Y}^{*}(n g)$ | (90) |
| $\mathrm{R}_{\mathrm{Y}}^{*}(\mathrm{ng})$ | (72) | * | (33) |
| $s$ | (79) |  |  |
| ${ }^{\text {imp }}$ | (76) | w | (79) |
| - - - - - | - - | $\mathrm{W}_{\mathrm{X}}$ | (77) |
| $\mathrm{S}_{\mathrm{X}}$ | (74) | $\mathrm{W}_{\mathrm{X}_{\text {dom }}}$ | (77) |
| $S_{X}(w)$ | (85) |  | (77) |
| $S_{X}(\mathrm{nw})$ | (80) | ${ }^{\text {X }}$ imp |  |
| ${ }^{s} \mathrm{x}_{\text {imp }}$ | (76) | $\mathrm{w}_{\mathrm{x}_{\mathrm{dom}}}^{q}$ | (83) |
| $S_{X}{ }_{(q)}^{q}$ | (80) | $\mathrm{W}_{\mathrm{X}_{\text {imp }}}^{\mathrm{q}}$ | (84) |
| $s_{x}{ }_{(g)}^{g}$ | (80) | $\mathrm{W}_{\mathrm{X}_{\mathrm{dom}}}^{\mathrm{q}}(\mathrm{ext})$ | (85) |
| $S_{X} \underset{(w)}{W}$ | (85) |  |  |


| $\mathrm{w}_{\mathrm{X}_{\text {imp }}} \mathrm{q}^{(e x t)}$ | (85) | Y | (8) |
| :---: | :---: | :---: | :---: |
|  |  | Y | (16) |
| ${ }^{W}$ | (78) | $Y_{\text {dom }}$ | (3) |
| $\mathrm{W}_{\mathbf{Y}_{\text {dom }}}$ |  | $Y_{\text {dom }}$ | (14) |
| ${ }^{\mathbf{w}} \mathbf{Y}_{\text {dom }}$ | (94) | $\mathrm{Y}_{\text {imp }}$ | (4) |
| X | (7) | $Y_{\text {imp }}$ | (15) |
| $\mathrm{X}_{\text {dom }}$ | (1) | $Y_{\text {dom, exp }}$ | (100) |
| $\mathrm{X}_{\text {imp }}$ | (2) | $Y_{\text {imp }}$, exp | (101) |
| $\mathrm{x}_{\text {imp }}$ | (24) | - - - - | - - |
| $\mathrm{x}^{\text {q }}$ | -- | $Y_{\text {dom }}(\mathrm{u})$ | (34) |
|  | (11) | $Y_{\text {dom }}(\mathrm{nu})$ | (35) |
| $\mathrm{x}_{\mathrm{dom}}^{\mathrm{q}}$ | (9) | $Y_{\text {imp }}(u)$ | (36) |
| $x_{i m p}^{q}$ | (10) | $\mathrm{Y}_{\text {imp }}(\mathrm{nu})$ | (37) |
| $\mathrm{x}_{\mathrm{dom}}^{\text {q }}$ (u) | (39) | Y (m) | (105) |
| $\mathrm{x}_{\mathrm{dom}}^{\mathrm{q}}$ ( nu$)$ | (40) | ( Y | (105) |
| $\mathrm{x}_{\text {imp }}^{\text {q }}$ (u) | (41) | $\Delta Y_{\text {dom }}$ | (105) |
|  |  | $\triangle \mathrm{Y}_{\text {imp }}$ | (105) |
| $\mathrm{x}_{\mathrm{imp}}^{\mathrm{q}}$ ( nu$)$ | (42) |  |  |
|  |  | Z | (5) |
| $\mathrm{X}^{\mathrm{q}}$ (m) | (107) | $z$ | (27) |
| $\Delta \mathrm{x}^{\text {q }}$ | (107) | $\mathrm{z}^{\text {q }}$ | (12) |
| $\Delta \mathrm{x}_{\text {dom }}{ }^{\text {q }}$ | (107) | $\mathrm{z}_{\mathrm{Y}}^{*}(\mathrm{dom})$ | (28) |
| $\Delta \mathrm{x}_{\mathrm{imp}}^{\mathrm{q}}$ | (107) |  |  |
|  |  | $z_{y}^{*}($ dom $)$ | (29) |
| $\mathrm{X}_{\mathrm{Y}}^{*}$ (imp, dir) | (25) |  |  |
| $\mathrm{X}_{\mathrm{y}}^{*}$ (imp, dir) | (26) |  |  |

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[^0]:    1. In order to keep the reporting of the user industry as consistent as possible with the supplier disaggregation and comparable with the input-output matrices, we have constructed a 43 by 66 matrix, the 23 extra user sectors representing services and final demand not surveyed as suppliers of innovation. In Table 1, the $1981-85$ innovation matrix is aggregated to a 12 by 23 matrix, and presented jointly with the 1982 total equirement and capital flow matrices.
[^1]:    a Estimated coefficients are shown next to the respective independent variables and the absolute value of the t-statistic is shown in parentheses. Time dumy variables for four time periods are included: 1958-63, 1963-67, 1967-72, and 1972-77. Coefficient estimates of the dumiry variables are not shown.
    b Sample size for the manufacturing sample is 95 (19 industries in 5 time periods). Sample size for all sectors is 250 ( 50 sectors in 5 time periods).

    * Significant at the .10 level (two-tailed test).
    ** Significant at the .05 level (two-tailed test).
    *** Significant at the .01 level (two-tailed test).

[^2]:    a Estimated coefficients are shown next to the respective independent variables and the absolute value of the t-statistic is shown in parentheses.
    b Sample size for the manufacturing sample is 95 (19 industries in 5 time periods). Sample size for all sectors is 250 ( 50 sectors in 5 time periods).

    * Significant at the .10 level (two-tailed test).
    ** Significant at the .05 level (two-tailed test).
    *** Significant at the .01 level (two-tailed test).

[^3]:    a Estimated coefficients are shown next to the respective independent variables and the absolute value of the t-statistic is shown in parentheses.
    b Sample size for the manufacturing sample is 95 (19 industries in 5 time periods). Sample size for all sectors is 250 ( 50 sectors in 5 time periods).

    * Significant at the .10 level (two-tailed test).
    ** Significant at the .05 level (two-tailed test).
    *** Significant at the .01 level (two-tailed test).

[^4]:    * We are thankful to Ms. Sumitra Chowdhury for computational help.

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[^6]:    ${ }^{3}$ This is obvious from $\sum_{p} f_{p q}^{c}=\lambda b_{\text {cq }}$, which is high when $q=c$.

[^7]:    ${ }^{4}$ See Oosterhaven (1988, 1989a) about other mixed interpretations from forward linkages; and Dietzenbacher et al. (1993) for a clear distinction between both types of linkages.
    ${ }^{5}$ This assumption was already made (implicitly) in the calculation of the Volume of the Column Fields of Influence.

[^8]:    ${ }^{6} \mathrm{~A}$ zero in the table has to be interpreted as an 'almost zero'. It denotes a percentage smaller than 0.5 .

[^9]:    ${ }^{7}$ and then, analogous to Table 3, over $c^{r}$ and $s$, where $c^{r}$ is the country-part of the combined index $c$

[^10]:    ${ }^{8}$ A comparable decomposition of EC income change between 1970 and 1980 is being made by van der Linden and Oosterhaven (1993).

[^11]:    We wish to thank Ronald Rioux for help in the preparation of the data, and the editor and two anonymous referees for their constructive comments and suggestions.

[^12]:    8 It is not necessary to specify a functional form for the domestic demand for non-differentiated commodities.
    9 Preserving relevant aspects linear structure through log-linear demand functions is not new - see Johansen (1960), for example.

[^13]:    25 Certainly we would not advocate a policy of "picking winners" on the basis of a single year of data.
    26 We are not alone in finding a strongly negative return in the Petroleum Refining industry. For example, Denny et al. (1991) find that relative to the American Refined Petroleum and Coal industry, competitiveness in the Canadian industry changed by $-127.2 \%$ over the period 1975-1985 (Table 2). The average change is $1.4 \%$ in the other 9 manufacturing industries which they consider (Table 2).
    27 This may misrepresent actual policy however. It is arguable that Canadian federal and provincial governments have actively encouraged this industry.

[^14]:    A comparison of the equations set out in Tables 5 and 8 reveals that the Stone model and the general linear model will be consistent with each other if and only if

[^15]:    1 "System of National Accounts" - United Nations - 1968, para 1.6

[^16]:    ${ }^{2}$ This procedure is put forward in a United Nations document: Methodological Studies - Series F - No. 39-1987

[^17]:    ${ }^{3}$ A detailed presentation of the proposed method can be found in Construire les comptes de la Nation (Constructing the National Accounts), Michel Séruzier, la Documentation Française, Paris 1988. See in particular chapters 7 to 10 for the IOT in the benchmark year, and Chapter 11 for the current years.

[^18]:    ${ }^{4}$ In chronological order, the following are the countries in which such IOTs have been put together: Columbia, Equator, Portugal, Peru, Brazil, Columbia, Central African Republic and Greece. The starting point for this professional experience has its roots in French National Accounts compilation practice.

[^19]:    5 A description of these methods can be found in: "LeTES au service de la mesure de l'économie non enregistrée. Propositions méthodologiques pour les pays en développement"- M. Séruzier - STATECO No. 58-59 - June 1989.
    6 A detailed presentation of these methods and a tentative definition of the informal sector can be found in : "Economie non enregistrée par la statistique et secteur informel dans les pays en développement"-François Roubaud and Michel Séruzier - STATECO No. 68 - December 1991.

[^20]:    ${ }^{1}$ The plant-level data on specified materials use is drawn from the Longitudinal Research Database, which is described in McGuckin and Pascoe (1988).

[^21]:    ${ }^{2}$ This assumption ignores a censoring constraint that is discussed further in the following section. The censoring constraint likely biases the bound on $a_{i j}^{c}$ downward slightly, leading to an understatement of the importance of measurement error in explaining the problem of negatives.

[^22]:    ${ }^{3}$ Triplett(1992) argues that the grouping of establishments with quite different production functions into a single SIC category also might be the cause of failures in attempts to estimate establishment-level production functions.

[^23]:    ${ }^{4}$ Any plant with total output less than 10,000 dollars is assumed to have all detailed materials use censored, so the censoring threshold in (14) is well-defined

[^24]:    ${ }^{5}$ To estimate this alternative, I do not actually rely on the normality or symmetry assumptions of 11 . The test statistic has the appropriate size and power to find heterogeneity under a wide class of bimodal distributions.

[^25]:    ${ }^{6}$ Newey (1987) suggests applying the Hausman test in a context like this, where tobit maximum likelihood estimates are being compared with CLAD estimates.

[^26]:    The views expressed in this paper are those of the authors and should not be attributed to the U.S. International Trade Commission. The authors would like to thank Mary Burfisher, Duane Hayes, Ronald Rioux, and Horacio Sobarzo for data, Mary Burfisher and Karen Thierfelder for helpful conversations, and Ranjit Dighe for research assistance.

    1 See also Robinson (1989).

[^27]:    ${ }^{2}$ Stone (1981 and 1986) describes macroeconomic SAMs in greater detail.
    ${ }^{3}$ In the detailed accounts, activities also purchase intermediate inputs.

[^28]:    4 Mexican maquila exports to the United States as reported in USITC (1991) were adder to total Mexican imports and exports as reported in Estados Unidos Mexicanos (1990). Mexican tracle with the U.S. and Canada as reported in USDOC (1988) and Globerman and Bader (1991) were subtracted from these new totals to obtain Mexico's trade with the rest of the world.
    5 This is consistent with the representative consumer specification used in much CGE based, comparative static welfare analysis.

[^29]:    ${ }^{6}$ On the RAS procedure, see Stone and Brown (1965).

[^30]:    7 The CGE model is discussed in Roland-Hoist, Reinert, and Shiells (1992).
    ${ }^{8}$ On linear multipliers, see Pyatt and Round (1979), Stone (1985), and Roland-Holst (1990). On the regional decomposition of linear multipliers, see Round (1985).

[^31]:    ${ }^{9}$ See Roland-Holst (1990) for a discussion of the differences between these two types of SAM multipliers.

[^32]:    10 See, e.g., the satellite account technique proposed by Barker (1990).

[^33]:    1. The origins of the SAM lie with Pyatt and Thorbecke [1976] and Pyatt and Doe [1977], who built on earlier work by Stone. More information on SAMs can also be found in e.E. Pratt and Round [1988] and Alarcon, van Hemest. Kouning, de Ruijter and Vos [1991].
     foot note 3]. That chaptor greatly benefited from coments provided by bloem, Hewaca, Pyatt, van Tonseren, Vanoli and any others. Hutatis mutandis, the same thus applies to the preseat text.
    2. This paper lits in a broader study by the author concerning the application of the SMA's SM4chapter to the case of Indonesia [Kounine, 1993 (forthcomins)]. That study serves to democstrate that the compilation and analysis of two comparable SESAME spannins a fiveryear period mey yield nev insights in the causes and consequences of social and econonic developent.
    3. Obviously, a SAM also has various features in common with the 1968 SMA'a table that illustratas the complete aystem [United Mationa, 1968: table 2.1]. Contrary to that table, a SAM containa row and colum totals and subdivisions of e.s. compenation of amployesa and the bousehold aector. On the other hand, a SAM typically shows less detail on types of transactions.
[^34]:    5. Recent extaples of SAls in which some of the concepts explicitly deviate fron the central framork of the revised SMA are given in Pyatt [1992] and Bos, Hollanders and Kouning [1902].
[^35]:    6. As later tables will distinsuish more accounts, this objective antails that the coding in this table may seem rather odd.
[^36]:    7. Some time ago, a 1980 SAM for Indonesia was published by the Indonesian Central Bureau of Statistics [Biro Pusat Statiatik, 1986]. This SAM, an earlier published 1075 SAM (Biro Pusat Statistik, 1982] and a 1975 integrated accounting system compiled by Downey [1984] have been used by the author of this paper as a point of departure to build new, more comparable SESAREa for these years. Amons other things, this implied that the plasibility of all kinds of growth rates, in current prices as well as in constant prices, was takon into eccount (cf. Keuning [1993, forthcomingl). Moreover, a closer connection with the revised SMA's SAM-chapter was established.
[^37]:    9. In fact, all presently available national accounts can easily be traneformed into e Mational Accounting Matrix (MAM). This is illustrated for the Netherlands in Kounins and de Gift [1992]. The Dutch MAM contains a complete set of transaction accounts, that is, including both Supply and Use Tables and account: for institutional aectora and accounts for financial assats. This integrated presentation appeara to be particularly illumineting to those users who are feailiar with Input-Output tables.
    10. In viow of data limitations. the account for financial transactions has been replaced by a financial balance eccount in this case (see subsection 3.4 below). Moreover, the revised SMA's Redistribution of Inccose in Kind Account and Use of Adjusted Disposable Income Account are not included in the SAM proper (see section 5 and foot note 35 below).
[^38]:    13. This so-called operating leasing is to be distinguished from financial leasing, waich should be recorded just like financial intermediation services in production accounts and input-output tables (Keunins, 1990].
    14. Even this can only serve as rough approximation of the actual quality of the services derived from fixed capital stock (cf. Ward [1992]).
[^39]:    15. A useful subdivision ia given in the rovieed SKA [United Nations, 1992: Annex IV, Part I]. An intricate statistical problem is that these asseta are typically owned by enterprisea but uaed by atablimhments.
[^40]:    18. In accordance with the revised SRA's prescriptiona, property income from and to abroad in the Indonesian SAMs includes reinvested earnings on direct foreign investment. The counterbalancing direct foreign investment itself is not shown as our SAMs do not distinguish separate
    categories of transactions in financial inatruments (see the next subsection).
[^41]:    19. Refer to Thorbecke and associates [1992] for a 1980 Indonesian SAM including finameial flow
    20. In principle, purchases of land and other non-produced assets are also recorded in cells (7,7), (7,11) and (11,7). If only the balance of purchases and sales of these assets is known by sector, this may be shown in an extra dumiy row which then adds up to zero (so that no extra columi is required): cf. Keuning and de Gijt [1992].
[^42]:    23. In the 1975 SAM , the income accruing to asricultural land has bean singled out and aubdivided by quality of the land (wet land/dry land) and by size of the land holding (14 subgroupa); refer to Downey [1984] and Keuning [1984].
[^43]:    27. Housohold receipts of unincorporated non-produced capital income senerated in agriculture include receipts minus inter-household payments of land rent in this case. Date limitations prevented a more correct recording of these flows, nemely in block (4_6, 4_6).
[^44]:    31. These are unrequited trensfers. Direct participation of the goverrment in the corporate sector is to be shown in a Pinancial account, wich is consolidated in this SAM.
[^45]:    32. In addition, labour income and coployment have been estimated jointly (see below) and the plasibility of the 1975-1980 srowth rates of all components has been checked.
[^46]:    33. An alternative is to incorporate belance shoets in the SAM (cf. Pyatt [1981b: table 10] and table XX. 7 in the revised SNA).
    34. If all fixed capital formation is registered when the aset ia ready for use, the volumeeffect is the capacity increase of the investing industry expressed in termat of maxims output volume (s), and the 'price-effect' is the price per volume unit of capital formation, that is, the investment value divided by the investment volume. As reault, the capacity effects of investment are conceptually integrated in a national accounte frememork.
[^47]:    36. This explicit reference to the derivation of core et of economic and social indicators can In lact be seen as a distinguishing feature of a SESNE. In this reapect, the cmatral frimework of the revised SMA is somewhat more limited as it does not provide the meso-data that underlie Indicatort for e.s. (un)employment and educational ettainemt. The scope of the ssos is generally much broader, but its linkage to egsregate economic and anvironnental dndicators is less explicit.
    37. An exemple mey serve to illustrate this point. If one aimed at maximising a policy objective operationalized by an isolated indicator (e.s. Eluman Development Index or a Coneumer Price Indax that is based on a consumption concept which (silghtly) deviates from the one used in the national accounts), one might come up with measures that supposedly lead to better value of thit indicator. However, it would be impossible to assess the repercussions of enother value of this indicator on other socio-economic objectives, as operationalized by other agsegete indicators.
[^48]:    38. Thus far the SESANE concept has been applied in various satellite frameworks, such as a National Accounting Matrix Includins Environmental Accounts (NANEA) [de Boo, Bosch, Gorter and Kounins. 1991; Keunins, 1992a] and a framowork incorporatins the production of umpaid dowestic and personal services for own consumption within households [Kazemier and Exel, 1992]. In these information aystems, non-monetary data have a crucial role to play.
